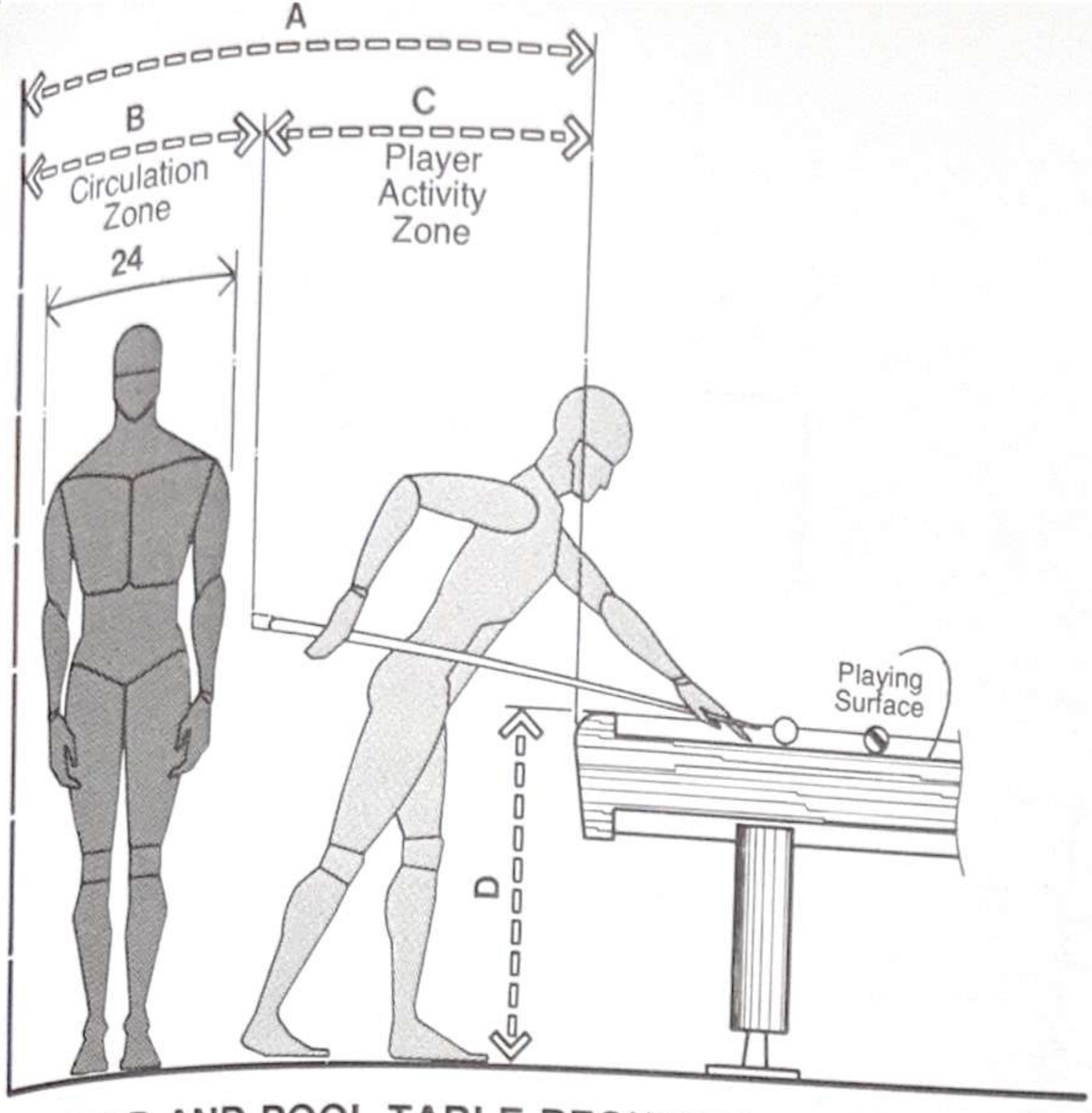
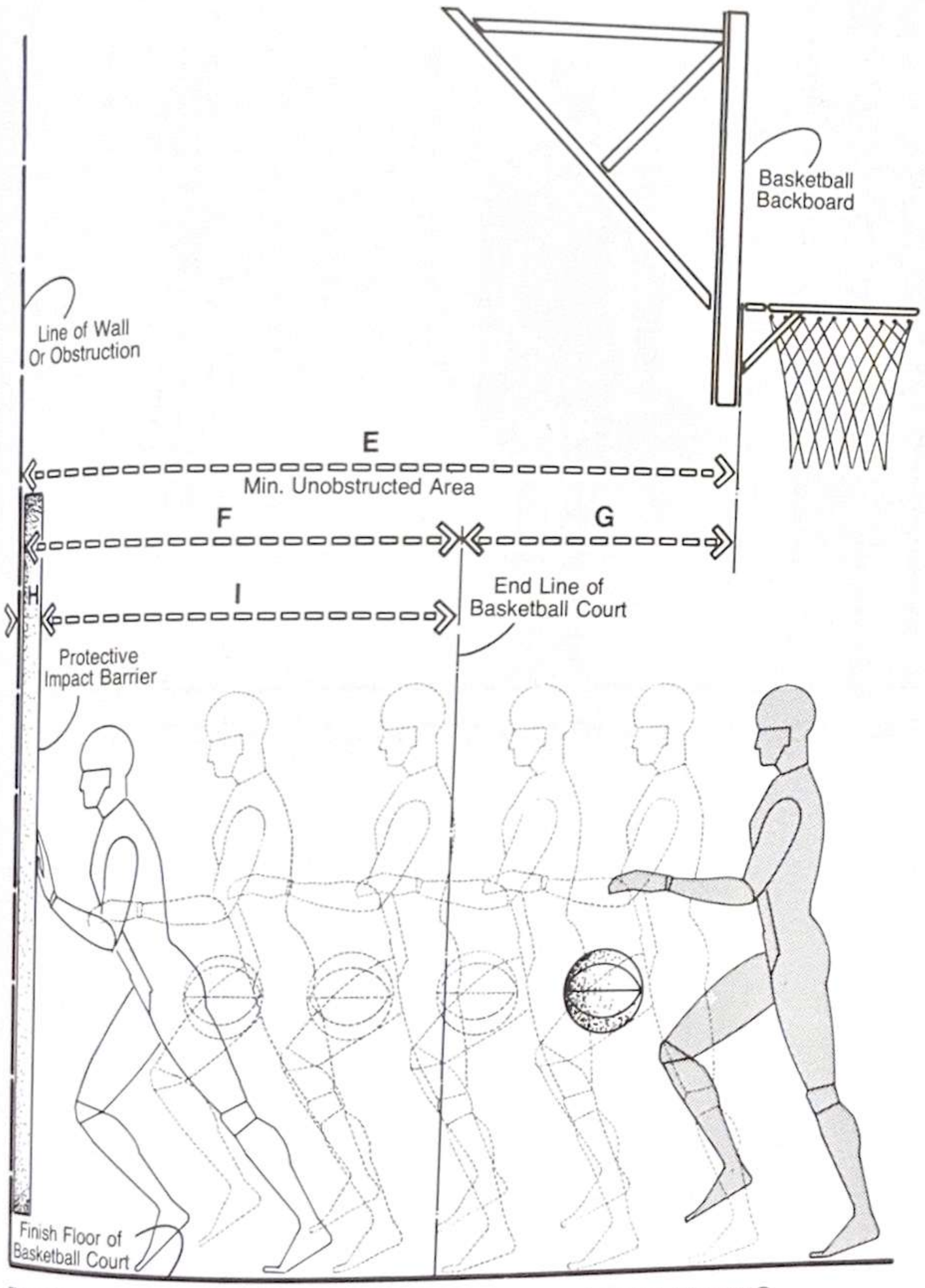


BILLIARD AND POOL TABLE REQUIREMENTS



BASKETBALL COURT / SAFETY AREA CLEARANCES

7.2 SPORTS AND GAMES

The top drawing indicates the clearance required from the edge of a pool or billiard table to the wall or nearest physical obstruction. A clearance of 60 to 72 in, or 152.4 to 182.9 cm, is suggested to allow the possibility for some circulation behind the active player. The activity zone shown applies for most shots. In some instances, due to the nature of the play, the stance of the player, and the length of the cue stick, there may be some intrusion into the circulation zone.

Safety zones and clearances around the perimeter of a basketball court are not included in codes and ordinances that presumably deal with the public safety. In relatively passive sports and games, the problem is not serious. In sports where the action is more intense, such as basketball, the lack of adequate safety zone clearances may cause injuries to the players and may even prove fatal.

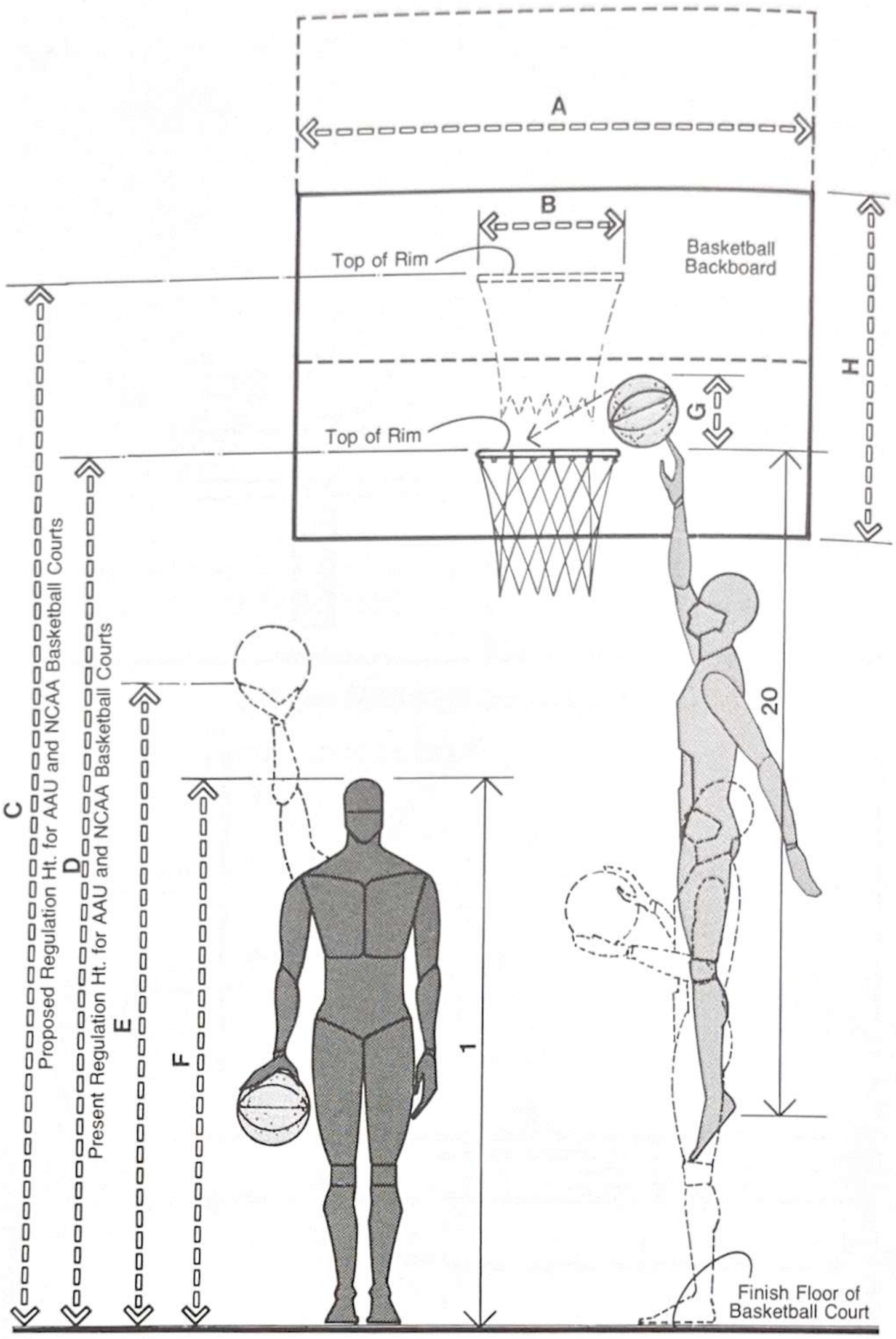
The drawing below suggests minimum clearances to allow the player, running and/or dribbling the ball at full speed, sufficient time and space to decelerate and stop before colliding with the wall.

	in	cm
A	60–72	152.4–182.9
B	30	76.2
C	30–42	76.2–106.7
D	33–34	83.8–86.4
E	142–172	360.7–436.9
F	94–124	238.8–315.0
G	48	121.9
H	4–8	10.2–20.3
I	90–116	228.6–294.6

Printed in China

7.2 SPORTS AND GAMES

The drawing here provides some useful information about human dimension and the sport of basketball. Aside from the dimensional data indicated, the subject serves as an excellent example of how anthropometric considerations relate to almost every facet of our daily life and, in fact, to most human activity. Many of the top professional basketball players have 99th percentile stature and reach dimensions. The extraordinary height and reach of some of these athletes, as well as jumping ability, enable them to do a so-called stuff shot. The player leaps high into the air, slightly above the rim of the basket, and literally stuffs the ball through. Such a player has a distinct advantage, totally unrelated to skill. To compensate for this, a proposal to raise the height of the rim on AAU and NCAA basketball courts is presently under consideration. The drawing shows the present rim height of 120 in, or 304.8 cm, and the proposed rim height of 144 in, or 365.8 cm. It is interesting to note that the top of the head of a player with a stature of 88 in, or 223.5 cm, is only 32 in, or 81.3 cm, below the rim.



BASKETBALL BACKBOARD AND RIM MODIFICATIONS

	in	cm
A	72	182.9
B	18	45.7
C	144	365.8
D	120	304.8
E	91–115	231.1–292.1
F	72–88	1829–223.5
G	9.6	24.4
H	48	121.9

7.3 WORK AND CRAFT CENTERS

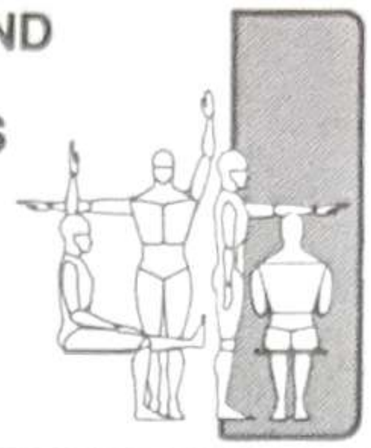


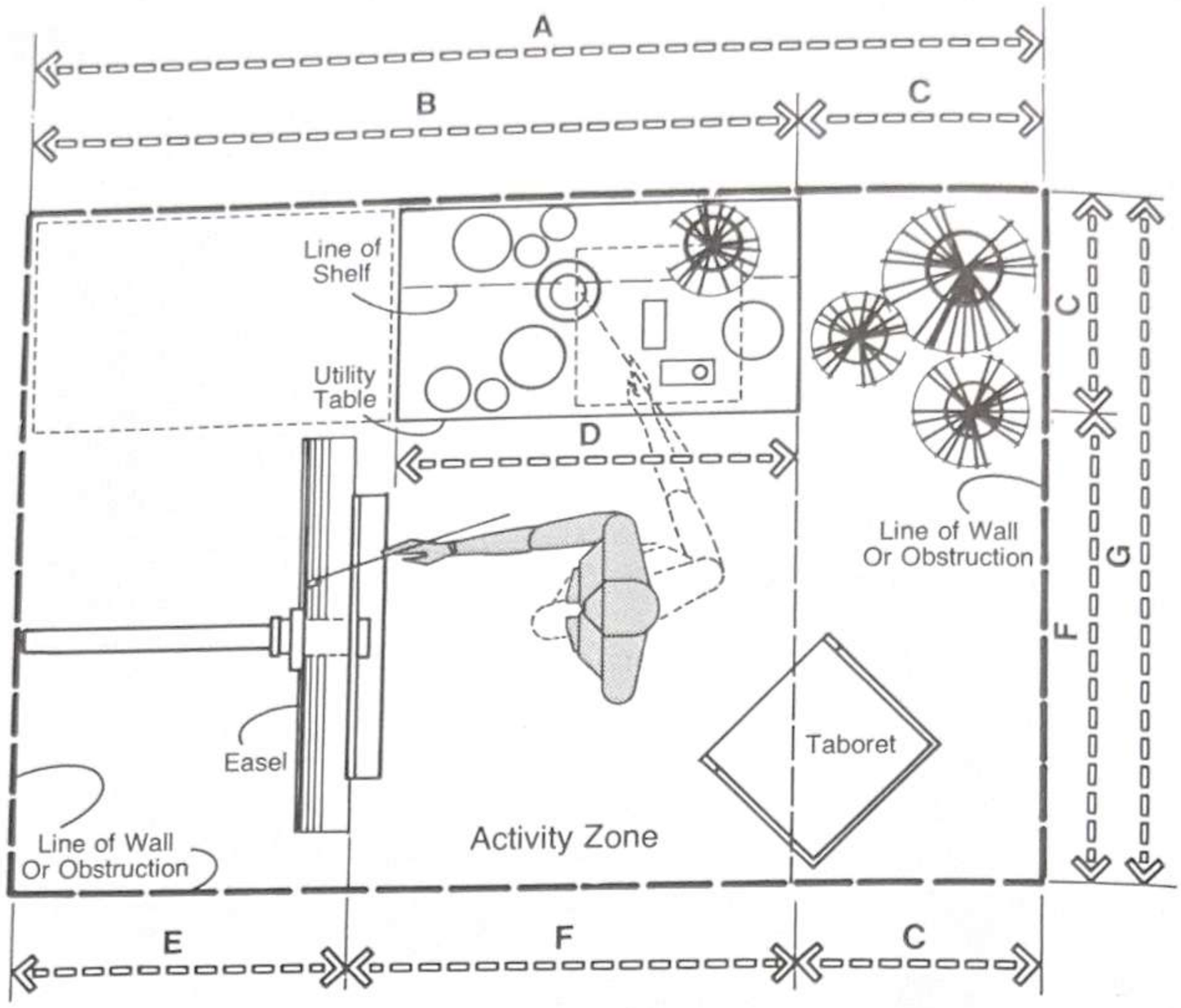
TABLE	PAINTING	DRAFTING	WORKSHOP	ART	ACTIVITIES / ANTHROPOMETRIC DATA
1A,2B,7B				◒	1 STATURE
1B,3C	◒			◒	2 EYE HEIGHT
1C,3B			◒	◒	3 ELBOW HEIGHT
1E,2D		◒		◒	5 SITTING HEIGHT NORMAL
1F,3G	◒				6 EYE HEIGHT SITTING
1K,2G				◒	11 ELBOW REST HEIGHT
1L,2H		●	●	●	12 THIGH CLEARANCE
1N,2J,7H		◒	◒	◒	14 POPLITEAL HEIGHT
1O,2K,7I		◒	◒	◒	15 BUTTOCK-POPLITEAL LENGTH
1U,4E		○			21 SIDE ARM REACH
1V,4D		○			22 THUMB TIP REACH
1W,6B			●		23 MAXIMUM BODY DEPTH
1X,6A		●		●	24 MAXIMUM BODY BREADTH

The drawings on the following pages illustrate the clearances suggested for use in making preliminary design assumptions about various types of work and craft spaces. The types involved are areas designed for painting, drafting, children's arts and crafts, and general workbench activities. It should be noted, however, that the drawings are not necessarily intended to show all the work and craft space types possible, nor in the spaces illustrated are all the tools or equipment normally associated with the activities necessarily indicated. To do so would require an entire volume of drawings dealing exclusively with work and craft spaces. The spaces included, however, were selected as representative of certain types of activities in order to illustrate some typical interface situations and the anthropometric considerations involved. One interesting anthropometric problem that applies to any child-oriented work and craft space is the obvious, radical difference in body size between the child and the instructor or teacher. If worksurfaces are designed exclusively to accommodate the body dimensions of the child, the height of the worksurface will be too low to accommodate the adult during any instructional activity or individual demonstration that involves the use of that surface. The approach, therefore, is a design that will reconcile the differences in body size and accommodate the needs of each. The problem is a difficult one and perhaps there is no perfect solution. A higher worksurface height and adjustable seat are one approach. Another may be of a more architectural nature and involves changes in floor levels within the space.

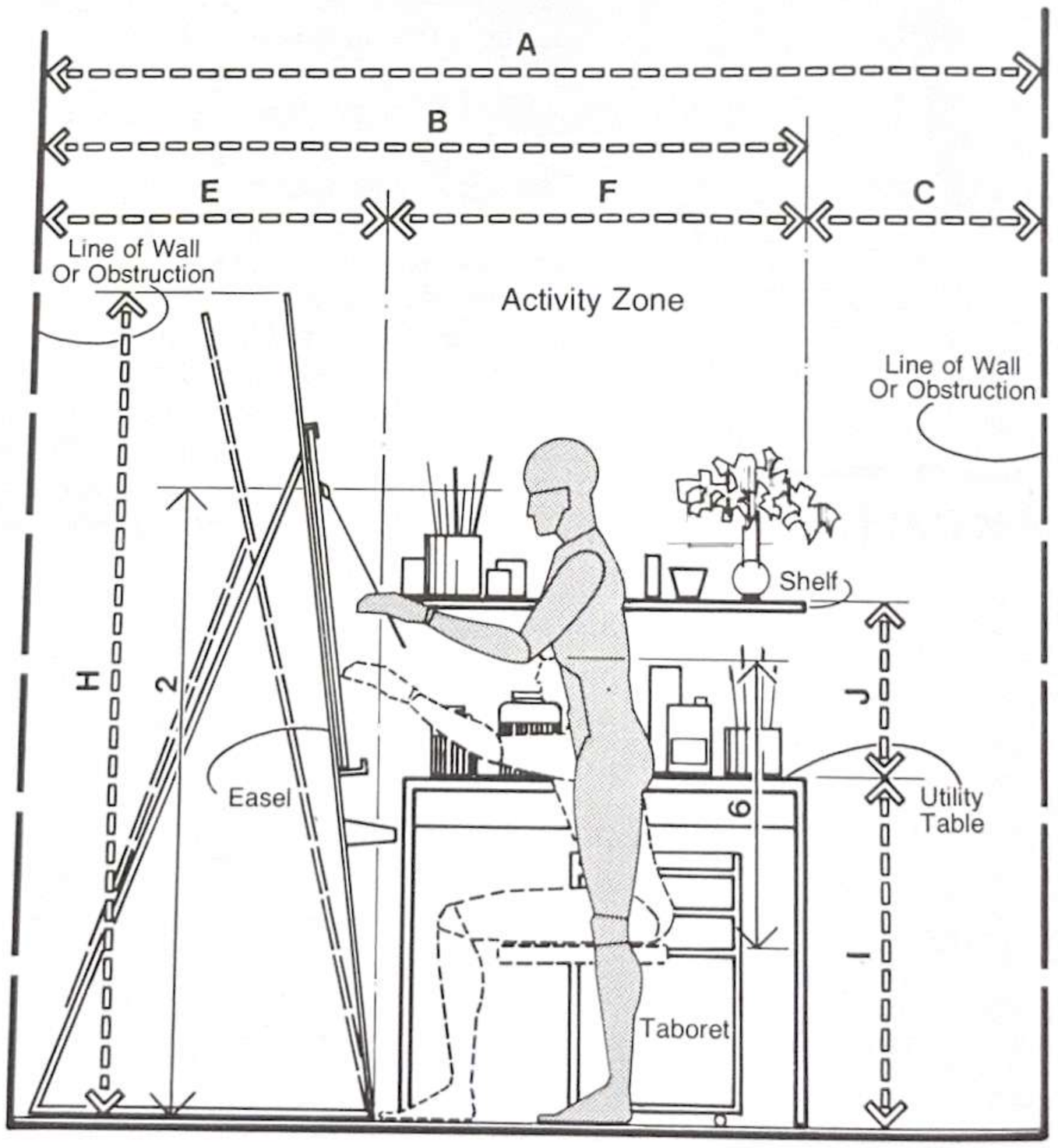
7.3 WORK AND CRAFT CENTERS

Most artists have individual preferences regarding the arrangement of their particular studio or workplace. In regard to human dimension and the artist's interface with his or her space, the factors to consider also vary greatly. Techniques, media, style, process all impact on the anthropometric requirements. The top drawing, therefore, should not be taken too literally. It is not intended to illustrate in detail a specific plan that will necessarily be responsive to the personal needs of all artists. It is intended simply to illustrate some of the components of the space. The anthropometric considerations involved must be examined with respect to the individual artist and the specific activities involved.

There are, however, some basic considerations that apply in most situations. Vertical reach from a standing and sitting position is helpful in locating shelving for art supplies. Side and forward arm reach measurements can be useful in locating various components of the space, relative to each other and the artist, in the most efficient manner possible. The eye height of a seated and standing person can be used to determine the location of visual displays and reference materials above the floor. Elbow height can be extremely helpful in establishing the height of a utility table. The text related to workbenches on the following pages of this section is also applicable to the artist's utility or prep table.

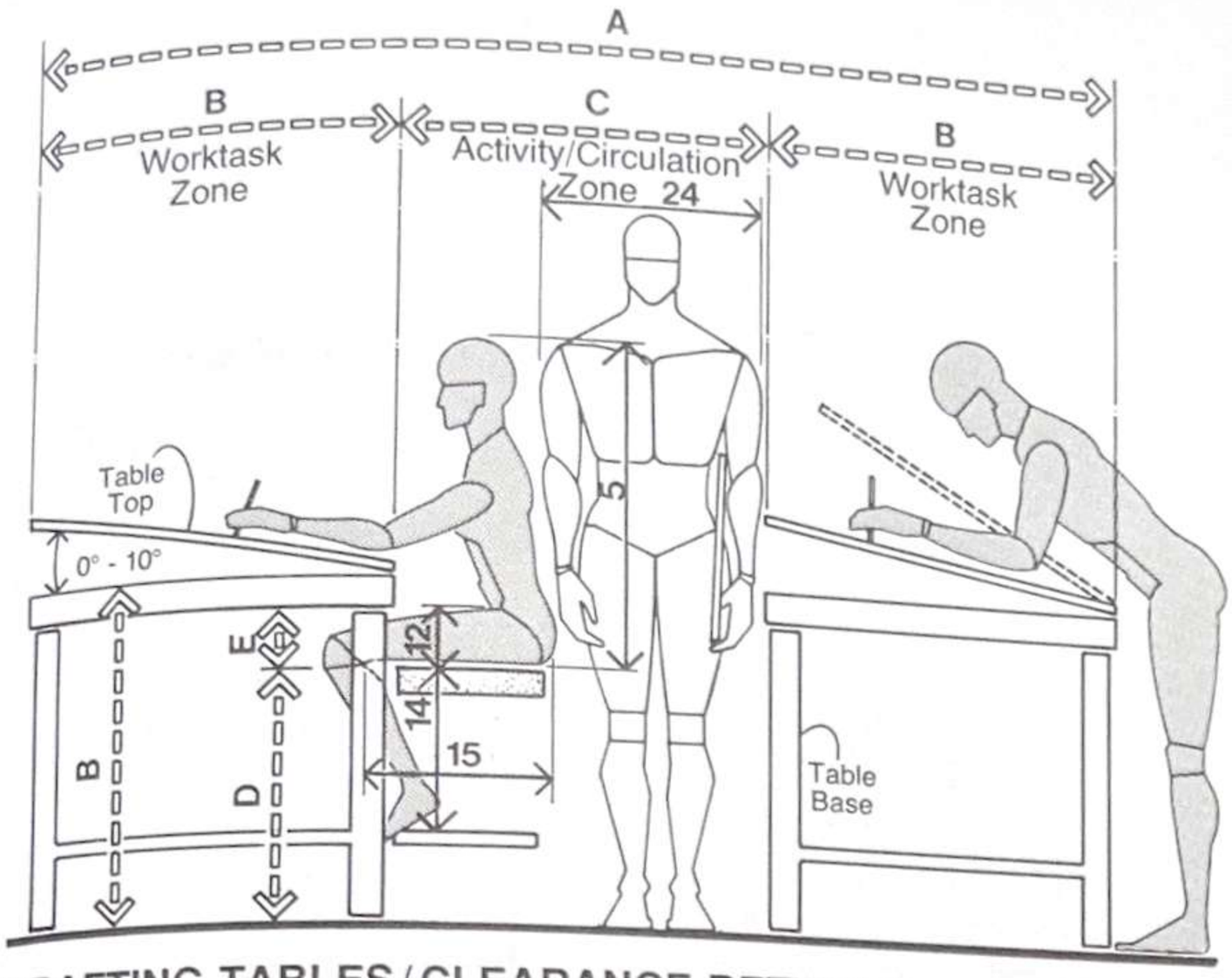


PAINTING FACILITIES

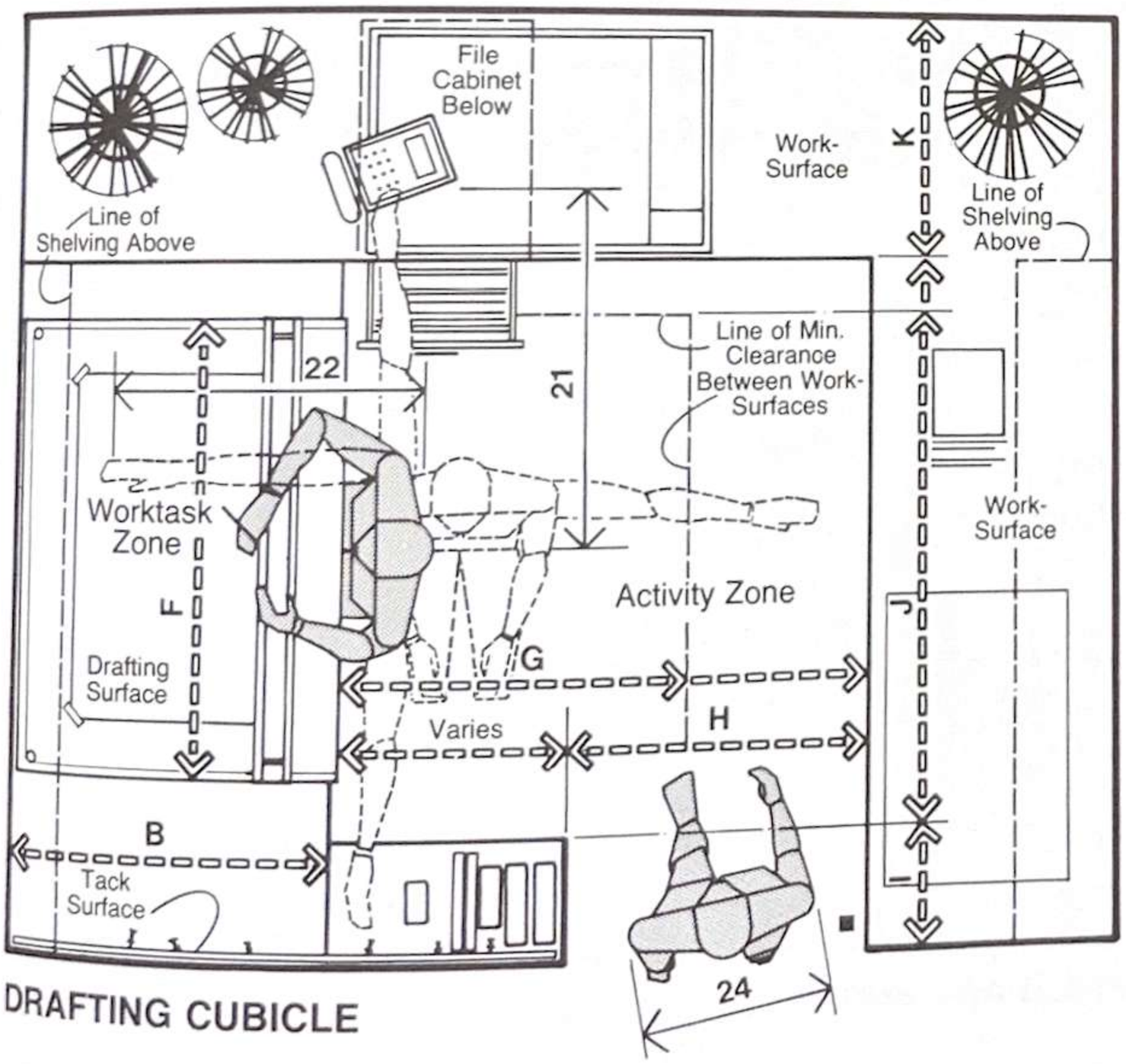


PAINTING FACILITIES

	in	cm
A	108	274.3
B	84	213.4
C	24	61.0
D	42	106.7
E	36	91.4
F	48	121.9
G	72	182.9
H	72–86	182.9–218.4
I	30–36	76.2–91.4
J	18	45.7



DRAFTING TABLES/CLEARANCE BETWEEN



DRAFTING CUBICLE

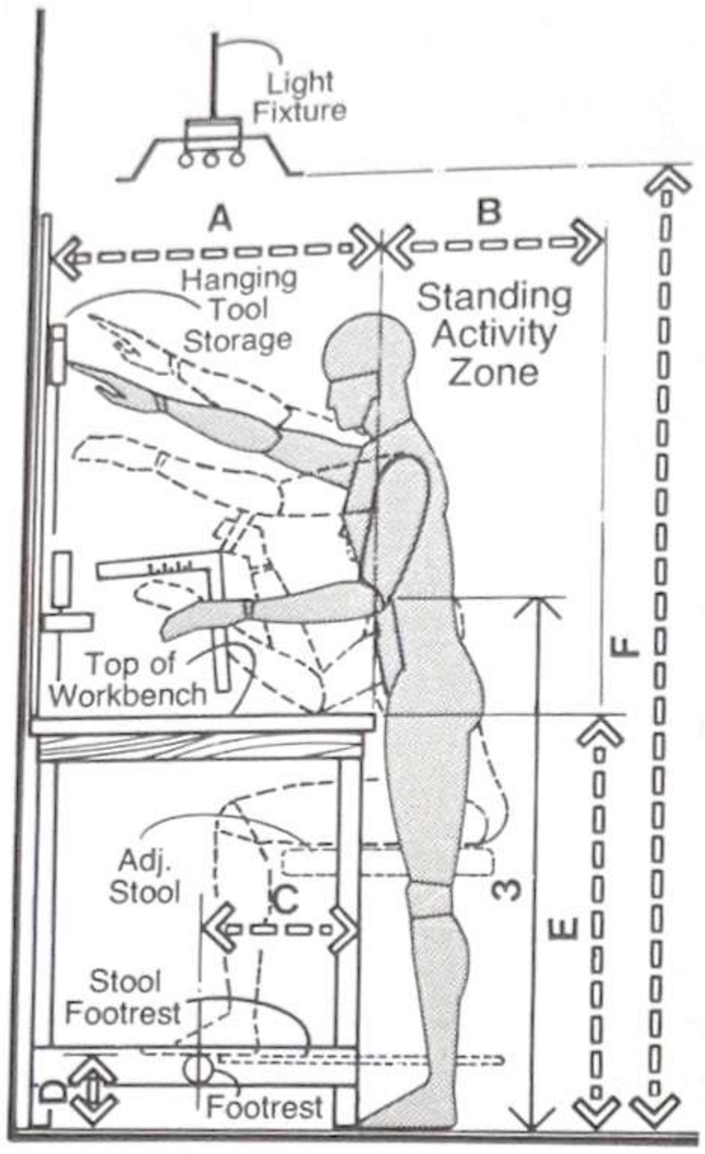
7.3 WORK AND CRAFT CENTERS

Workplaces for drafting and related types of activities for general group use or instructional purposes can be arranged on the basis of individual drafting tables, as shown in the top drawing, or as cubicles or workstations, as indicated in the bottom drawing. The top drawing shows the clearances involved between tables as well as the clearances necessary for proper interface between the seated and standing person and the table. A table height of 36 in, or 91.4 cm, as opposed to regular desk height, will permit use of the table from both a seated and a standing position. Proper minimum clearance between the top of the seat surface and the underside of the table, as shown, is essential. An adjustable stool can be extremely helpful in compensating for variability in body size. Provisions for a footrest are also a critical consideration. Because of the height of the table, the distance of the seat above the floor will invariably be higher than normal and exceed the popliteal height of most, if not all, intended users. This will cause the feet to dangle above the floor, resulting not only in a lack of proper body stability but pressure on the underside of the thigh just behind the knee. This pressure will cause irritation of the tissue involved and impede blood circulation, resulting in considerable discomfort. The lack of body stability will require compensatory muscular force to maintain equilibrium, resulting in additional discomfort and pain.

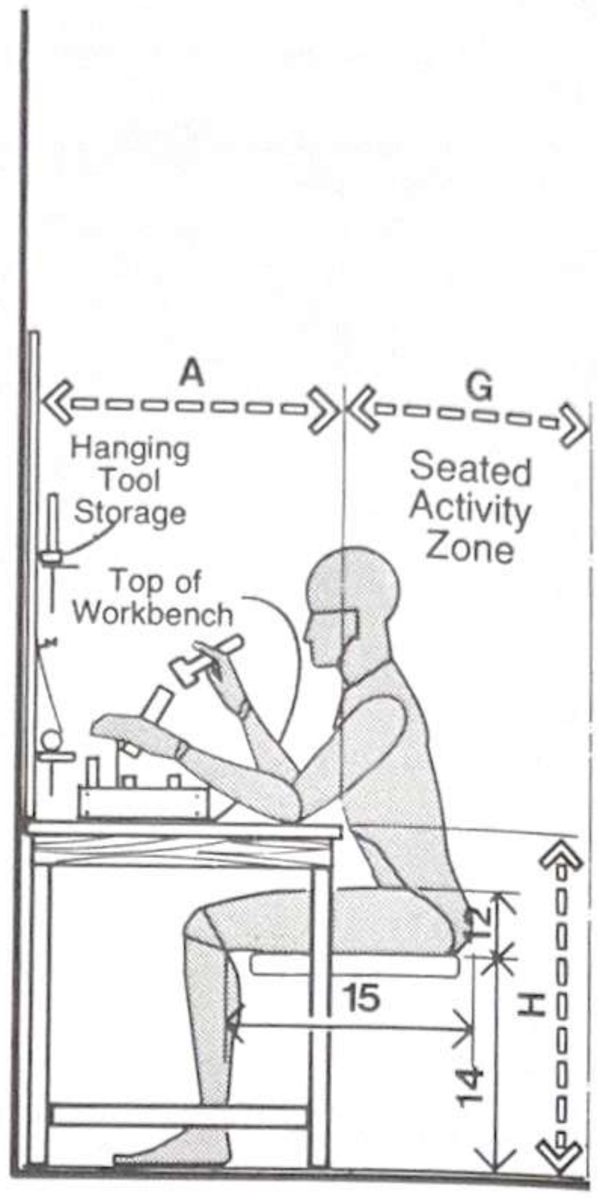
	in	cm
A	108–120	274.3–304.8
B	36	91.4
C	36–48	91.4–121.9
D	21–27.5	53.3–69.9
E	7.5	19.1
F	48–60	121.9–152.4
G	36–60	91.4–152.4
H	30	76.2
I	12	30.5
J	54–60	137.2–152.4
K	27–30	68.6–76.2

7.3 WORK AND CRAFTS CENTER

For standing work height, the height of the elbows above the floor (elbow height) should be considered. If considerable muscular force is required, the distance from the elbow to the top of the bench should be clearly greater. If minimal physical force is involved, a distance between the elbow and the bench top of between 3.5 and 6 in, or 8.9 and 15.2 cm, should be adequate. For preliminary design assumptions, a height of 34 to 36 in, or 86.4 to 91.4 cm, would be reasonable. In regard to bench heights for seated work, 24 to 29 in, or 60.9 to 73.6 cm, can be used for preliminary design assumptions. The limitations of human reach must also be taken into account in locating overhead tool storage. The bottom drawing indicates some of the critical dimensions related to an arts and crafts center for children ranging in age from 6 to 11 years. The critical anthropometric consideration is in making the design responsive to the body size of the child as well as the adult. A teacher forced to bend to the surface of tables scaled down to the body size of a child would suffer fatigue and backache in a short time. Adjustability in both chair and table, however, can reconcile the needs of differing requirements.

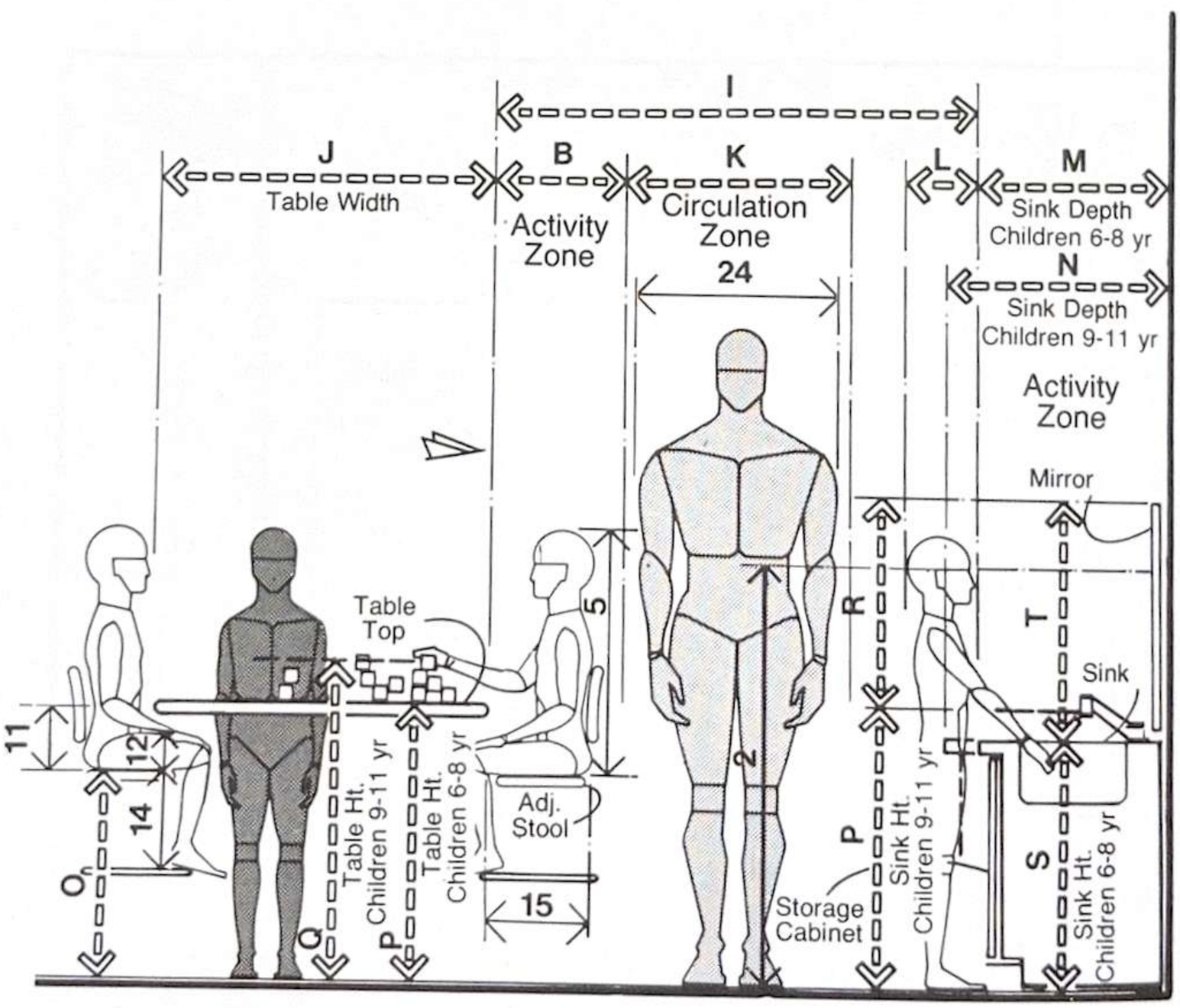


HIGH WORKBENCH



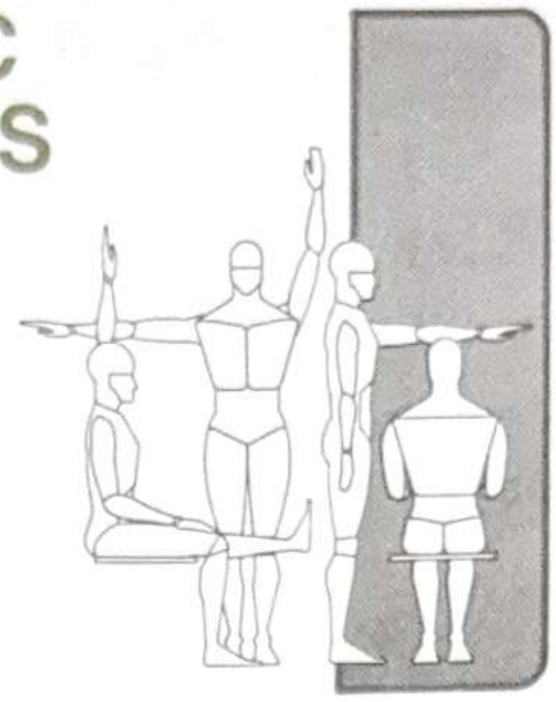
LOW WORKBENCH

	in	cm
A	18–36	45.7–91.4
B	18	45.7
C	6–9	15.2–22.9
D	7–9	17.8–22.9
E	34–36	86.4–91.4
F	84	213.4
G	18–24	45.7–61.0
H	29–30	73.7–76.2
I	65	165.1
J	36	91.4
K	30	76.2
L	15	38.1
M	21	53.3
N	24	61.0
O	22–27	55.9–68.6
P	29	73.7
Q	34	86.4
R	33	83.8
S	26	66.0
T	16	40.6



CHILD ART AND CRAFT CENTER

8 PUBLIC SPACES



TABLE

	8.1	8.2	8.3	8.4	SPACE ANTHROPOMETRIC DATA
1A,2B	●	●	◑		1 STATURE
1B,3C	◑	◑	●	◑	2 EYE HEIGHT
1C,3B				◑	3 ELBOW HEIGHT
					4 SITTING HEIGHT ERECT
1E,2D					5 SITTING HEIGHT NORMAL
1F,3G		○	○	◑	6 EYE HEIGHT SITTING
					7 MIDSHOULDER HEIGHT SITTING
					8 SHOULDER BREADTH
					9 ELBOW-TO-ELBOW BREADTH
					10 HIP BREADTH
					11 ELBOW REST HEIGHT
1L,2H				●	12 THIGH CLEARANCE
					13 KNEE HEIGHT
1N,2J				◑	14 POPLITEAL HEIGHT
1O,2K				◑	15 BUTTOCK-POPLITEAL LENGTH
1P,2L				●	16 BUTTOCK-KNEE LENGTH
					17 BUTTOCK-TOE LENGTH
					18 BUTTOCK-HEEL LENGTH
1S,4C					19 VERTICAL REACH HEIGHT SITTING
					20 VERTICAL GRIP REACH
					21 SIDE ARM REACH
1V,4D			○	○	22 THUMB TIP REACH
1W,6B	●	●	●	●	23 MAXIMUM BODY DEPTH
1X,6A	●	●	●		24 MAXIMUM BODY BREADTH

Public spaces, such as corridors, lobbies, and concourses, are subject to a tremendous intensity of usage involving fluctuating peaks of activity and human occupancy loads. In office buildings, peaks relate to working hours. In transportation facilities patterns of usage are dictated by arrival and departure activities. In theater, convention centers, or sports centers, scheduling of events determines the periods of occupancy. Adequate provisions for human locomotion through these public spaces, as well as provisions for related convenience facilities are important design considerations.

The quality of the interface between the human body and the interior space impacts not only on the level of user comfort involved, but on the public safety. To determine door widths, corridor widths, and stair dimensions, body size must be the ultimate yardstick. Caution should be exercised in accepting prevailing standards or rules of thumb to establish critical clearances without questioning their anthropometric validity, even though these standards may be incorporated into existing codes or ordinances. It serves no purpose to conform to the language and not the intent of these codes, which is to ensure the public safety. The unit or increment of measurement that must be applied to establish proper width clearances must reflect current published maximum body breadth dimensions. The data selected must accommodate the majority of users. This is too critical a factor to be based on antiquated rules of thumb. The design of public rest rooms must also reflect this unit of measurement if they are to function properly. It is absurd, for example, to provide the number of fixtures that may be required by codes if the spacing selected will only allow half of them to be used simultaneously. In addition, public spaces should be responsive to the needs of the disabled user. Controls should be within reach of chair-bound people, stair design should accommodate elderly people, and human locomotion for ambulant disabled people should be barrier free. The drawings on the following pages are intended to call attention to some of the anthropometric factors to be considered in the design of public spaces. The first of these drawings deals with the basic unit of measurement: the maximum body breadth and depth of the human body.

8.1 HORIZONTAL CIRCULATION SPACES

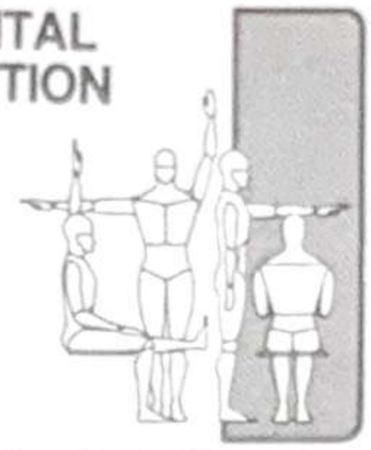


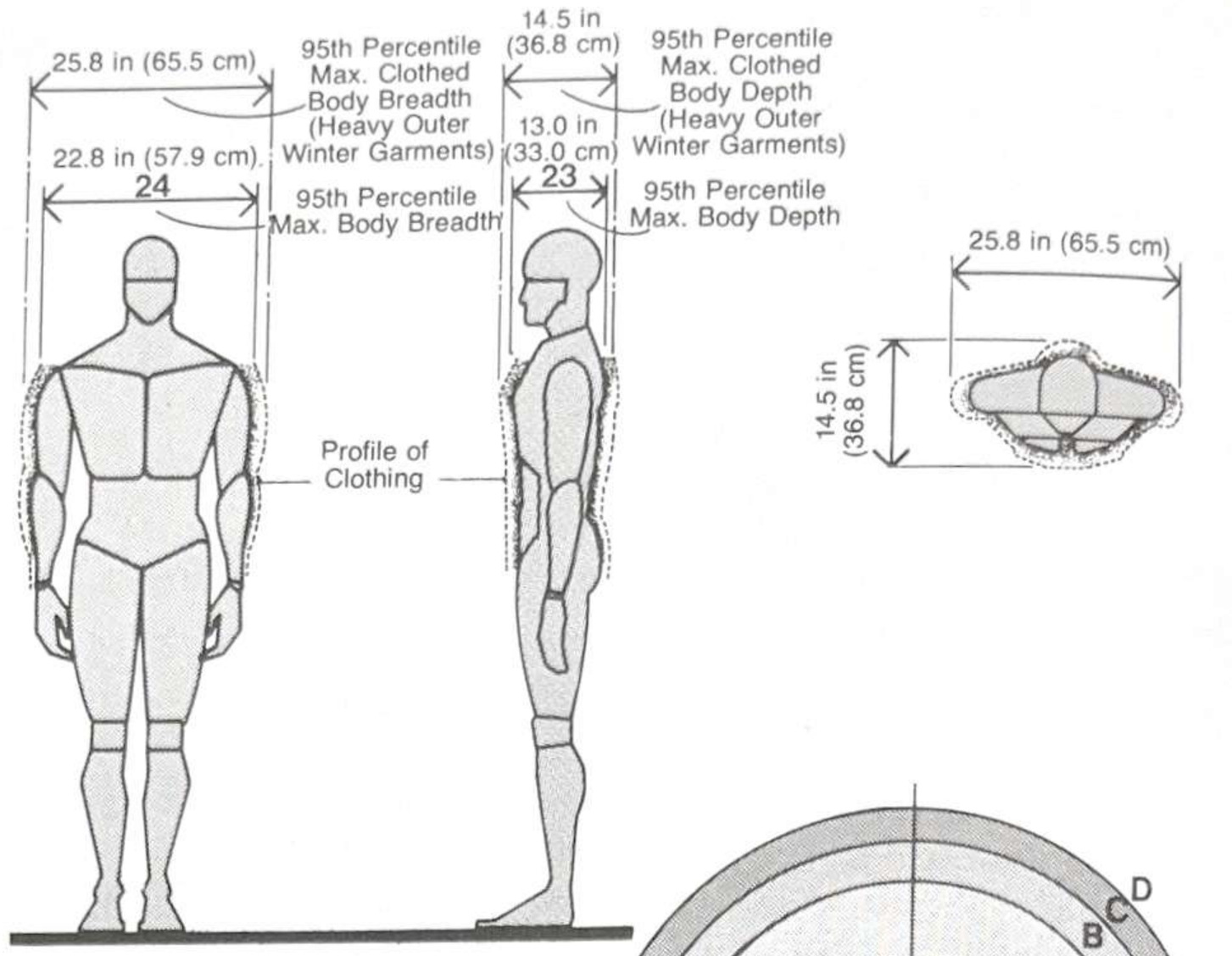
TABLE	CORRIDOR	QUEUING	ACTIVITIES	ANTHROPOMETRIC DATA
1A,2B		●		1 STATURE
1B,3C		◔		2 EYE HEIGHT
1W,6B	●	●		23 MAXIMUM BODY DEPTH
1X,6A	●	●		24 MAXIMUM BODY BREADTH

Horizontal circulation spaces may include typical corridors found in public buildings ranging from 60- to 144-in, or 152.4- to 365.8-cm wide, lobbies, pedestrian promenades, plazas in enclosed shopping malls, and large circulation and concourse areas in transportation terminals. Planning these spaces can be a fairly sophisticated and complicated matter, involving such factors as flow volume (usually expressed as pedestrians per foot width of walkway per minute), time and distance headways, walking speeds, queue lengths. The services of a traffic engineer or pedestrian planning specialist are usually required to properly design the larger spaces. Part of the process, no matter how sophisticated, is consideration of the human factor of body size and dimension. In addition some insight into physiological and psychological factors is also required. The intent here is to focus primarily on the anthropometric aspects, with the knowledge that this constitutes but a small part of the entire design process. The drawings on the following pages deal primarily with the human body and its maximum body depth and breadth as the basic increment of measurement. This incremental unit is then applied within the context of queuing situations and corridors.

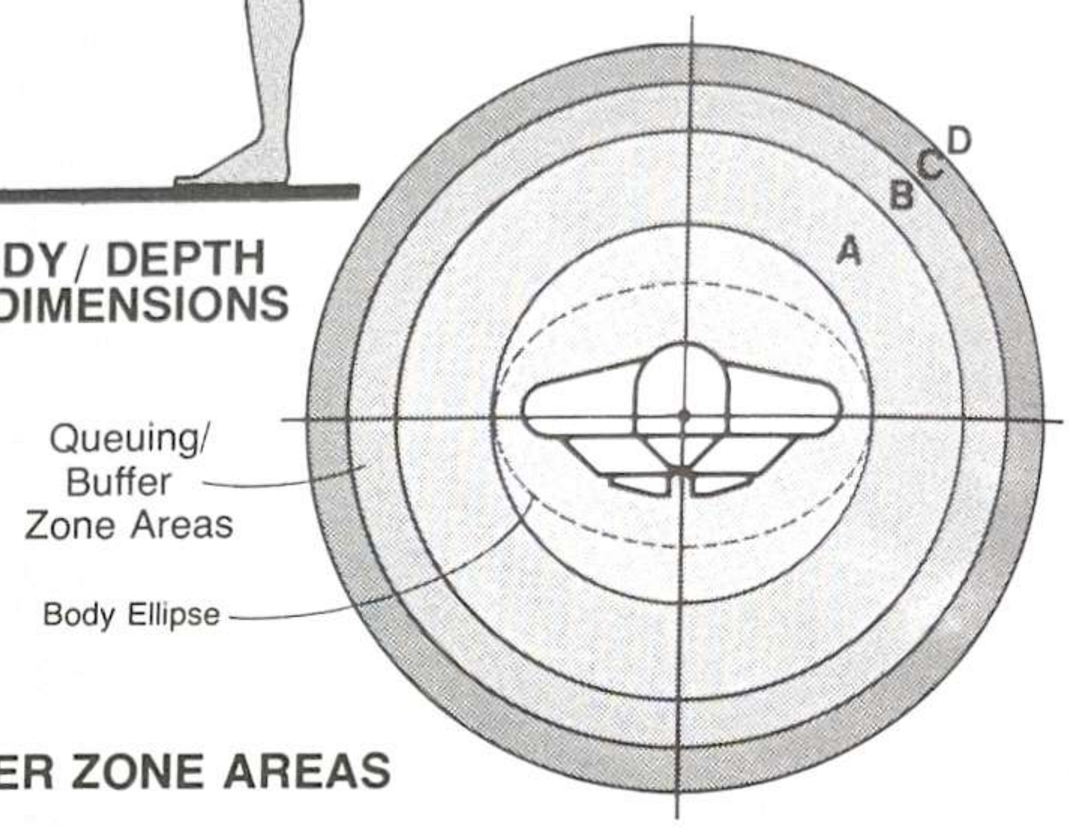
8.1 HORIZONTAL CIRCULATION SPACES

In dealing with pedestrian locomotion, the human body must serve as the basic increment of measure and the larger-size person as the model in establishing clearance dimensions. If such clearances accommodate larger people, they obviously can accommodate those of smaller body size. The top diagram shows three views of the human figure, including critical 95th percentile dimensions of the three anthropometric measurements. In establishing breadth and depth dimensions, an allowance of 3 in, or 7.6 cm, for garments, including heavy outer winter clothing, was used. The breadth dimension assumes that the clothing consists of six layers. Accordingly, the aggregate allowance of 3 in is assumed to be equally distributed: one layer on the inside and outside surface of both arms and one layer on each side of the torso. The overall dimension so calculated is 28.8 in, or 65.5 cm. Heretofore, the generally accepted measurement was 22 in, or 55.9 cm, presumably based on the shoulder breadth of an average person. The authors contend that this is not a valid figure, since the critical anthropometric measurement to be utilized should be body breadth, not shoulder breadth and "average" data do not accommodate the majority of the population.

The diagram and chart below should also prove useful in the design of circulation spaces. They have been adapted from a study of pedestrian movement and queuing by Dr. John Fruin to establish relative levels of service based on pedestrian density. The basic unit is the human body, which is envisioned as a so-called body ellipse of 18 by 24 in, or 45.6 by 61 cm.



THE HUMAN BODY / DEPTH AND BREADTH DIMENSIONS

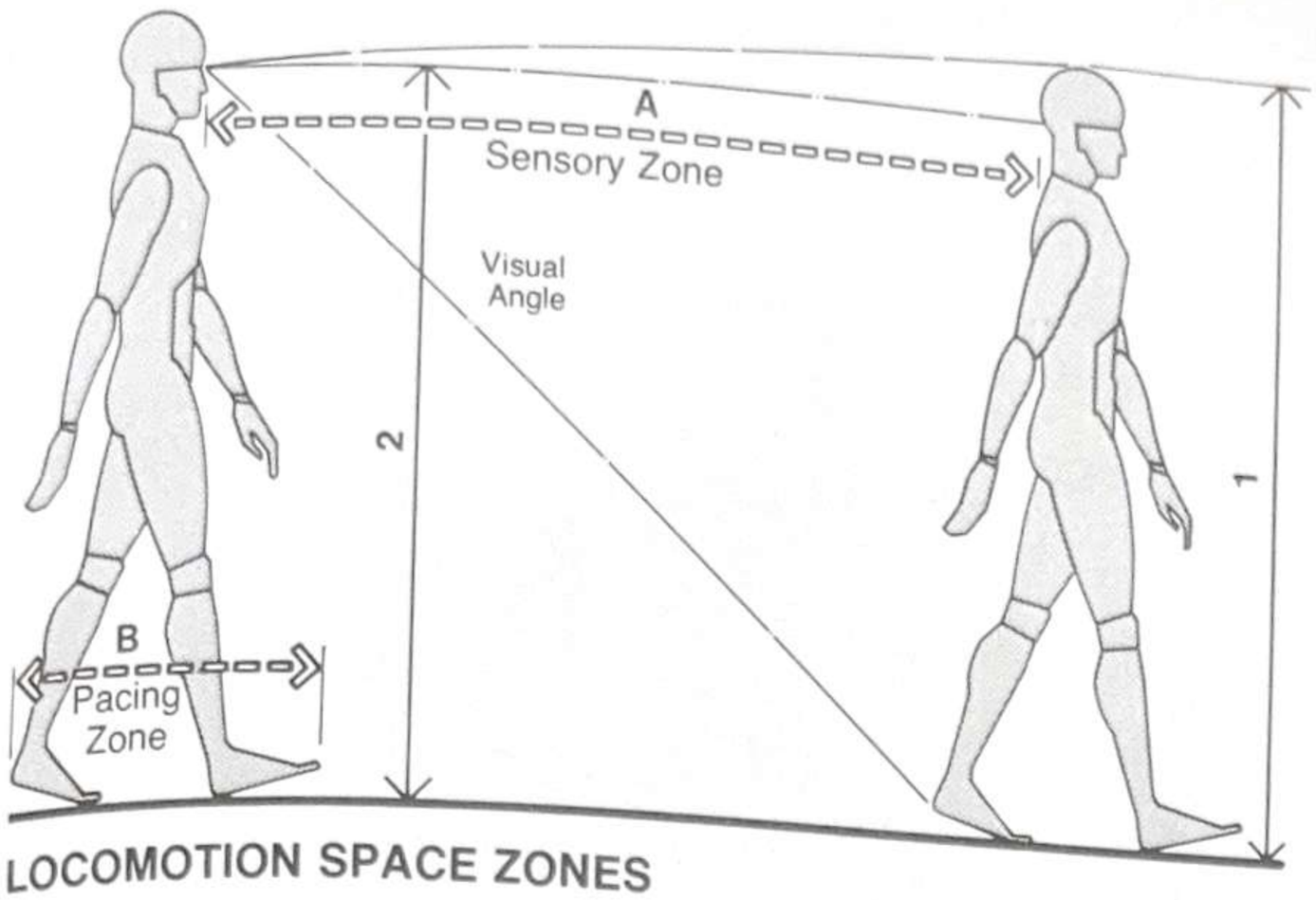


QUEUING / BUFFER ZONE AREAS

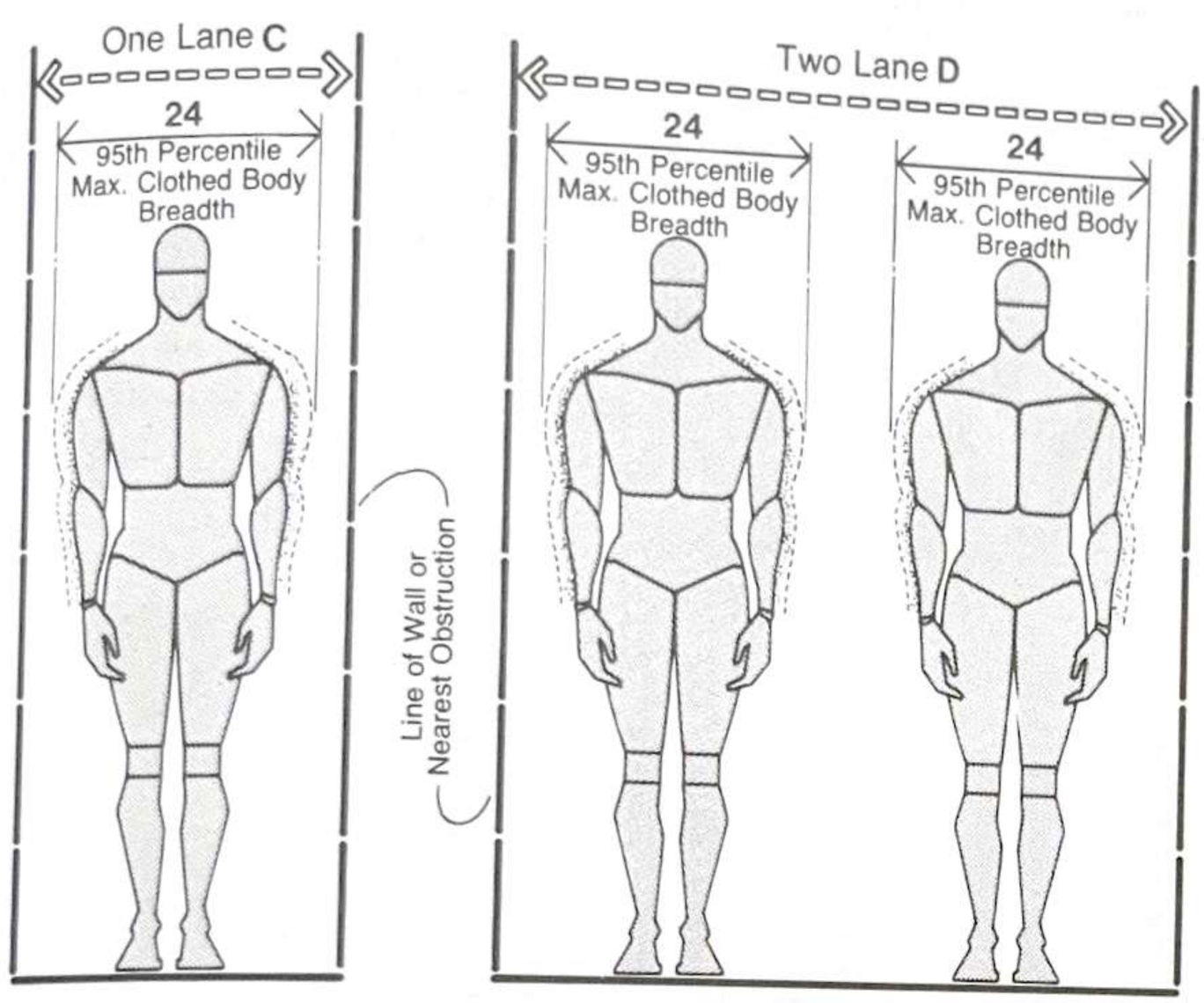
QUEUING DENSITY ANALYSIS*

DESIGNATION	DESCRIPTION	RADIUS in	RADIUS cm	AREA sq ft	AREA sq cm
A. Touch Zone	Below this area of occupancy, frequent unavoidable contact between people likely. No possibility of circulation within this zone. Movement restricted to shuffling. Occupancy similar to slightly crowded elevator.	12	30.5	3	.28
B. No-Touch Zone	Contact between people can be avoided as long as movement within area is not necessary. Movement possible as a group.	18	45.7	7	.65
C. Personal Zone	At this spacing a full body depth separates standees. Limited lateral circulation between people possible by moving sideways between them. Within range of spatial occupancy that has been selected in experiments emphasizing comfort standards.	21	53.3	10	.95
D. Circulation Zone	Circulation within queuing area possible without disturbing others.	24	61	13	1.4

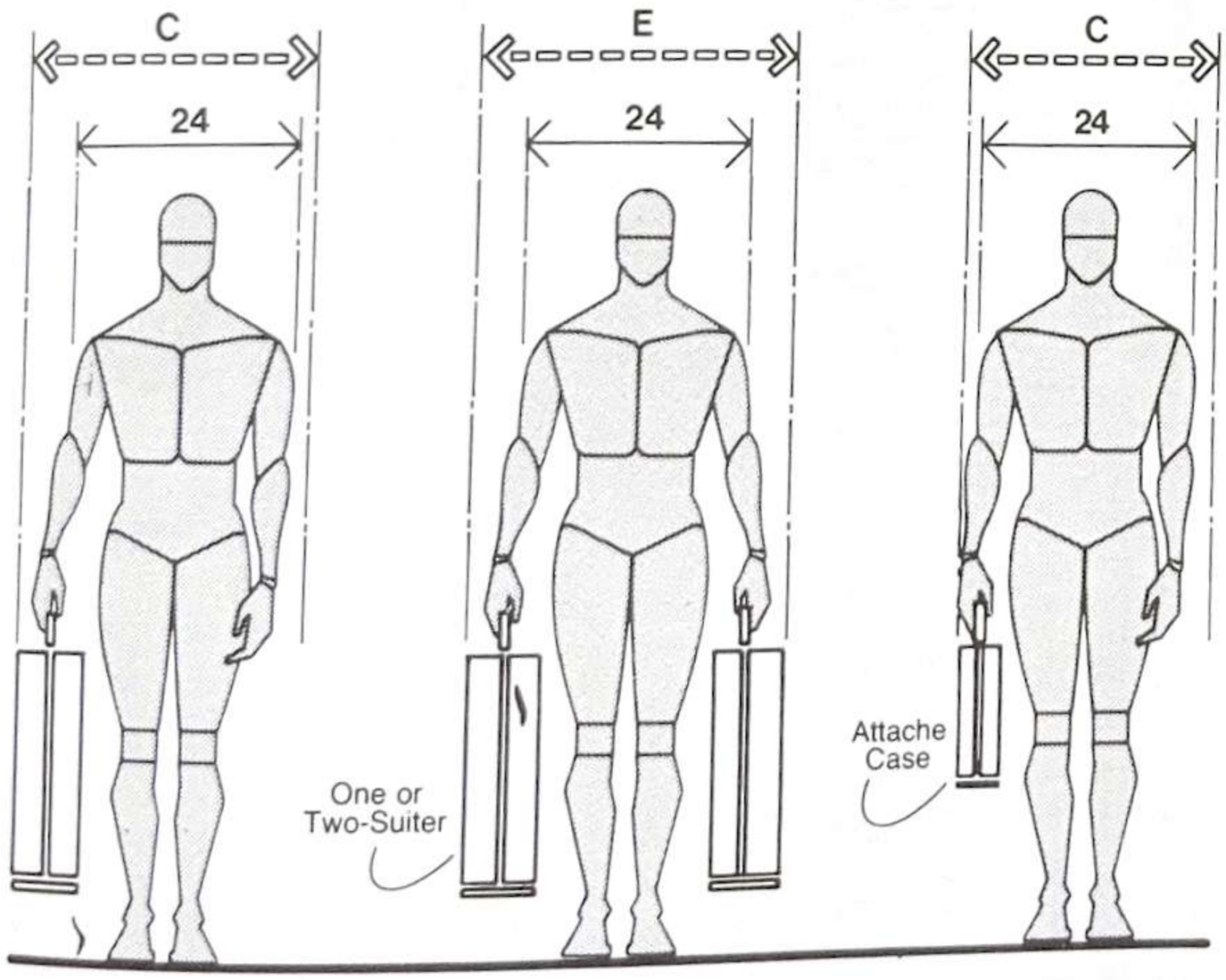
*Chart adapted from John J. Fruin, *Pedestrian Planning and Design* (New York: Metropolitan Association of Urban Designers and Environmental Planners, 1971).



LOCOMOTION SPACE ZONES



CIRCULATION / CORRIDORS AND PASSAGES



BODY BREADTH CLEARANCES WITH LUGGAGE

8.1 HORIZONTAL CIRCULATION SPACES

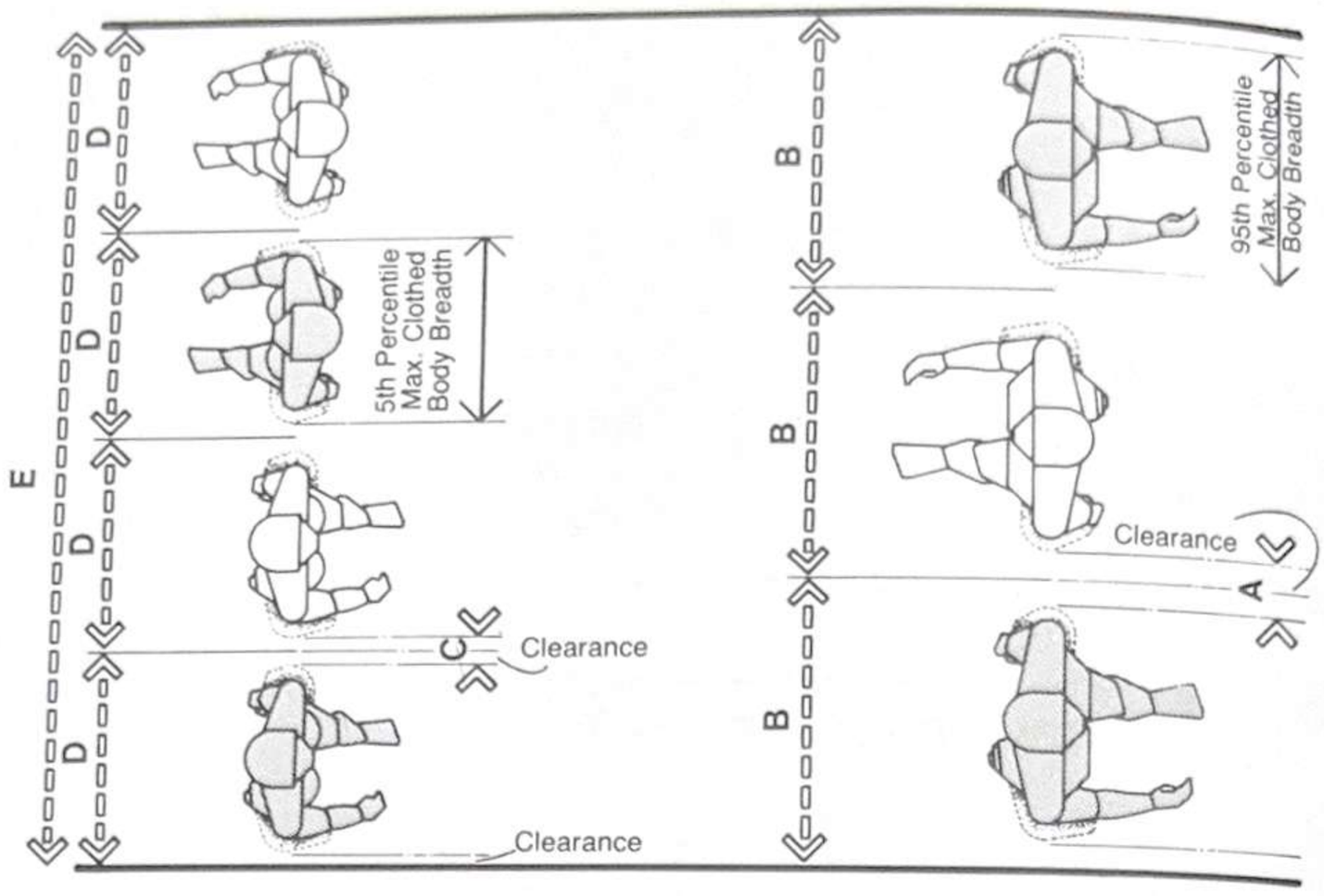
The top drawing illustrates the two zones involved in walking. The pacing zone is the distance required to place one foot in front of the other. This distance varies with the individual due to the many psychological, physiological, and cultural factors involved, as well as sex, age, and physical condition. Most adults, however, have a pacing distance of between 24 and 36 in, or 61 and 91.4 cm. The sensory zone is the distance required for perception, evaluation, and reaction in sufficient time to avoid danger, all while the body is in motion. The multitude of human factors involved makes measurement of this distance extremely difficult. One indicator, however, might be the distance one person has to be behind the other to observe him from head to toe. This is approximated to be about 84 in, or 213.4 cm, in a normal walking situation. In single- and double-lane corridors and passageways, clearances of 36 and 68 in, or 91.4 and 172.7 cm, respectively, are suggested. A 30-in, or 76.2-cm, minimum is suggested for a single lane with no physical obstructions on either side. If carrying items or pushing a small cart is involved, the 36-in minimum should still be used. The double-lane clearance allows for two people abreast to circulate comfortably without body contact. The drawing at the bottom of the page suggests the amount of space occupied by people carrying various types of hand luggage.

	in	cm
A	84	213.4
B	22–36	55.9–91.4
C	30–36	76.2–91.4
D	68	172.7
E	36–42	91.4–106.7

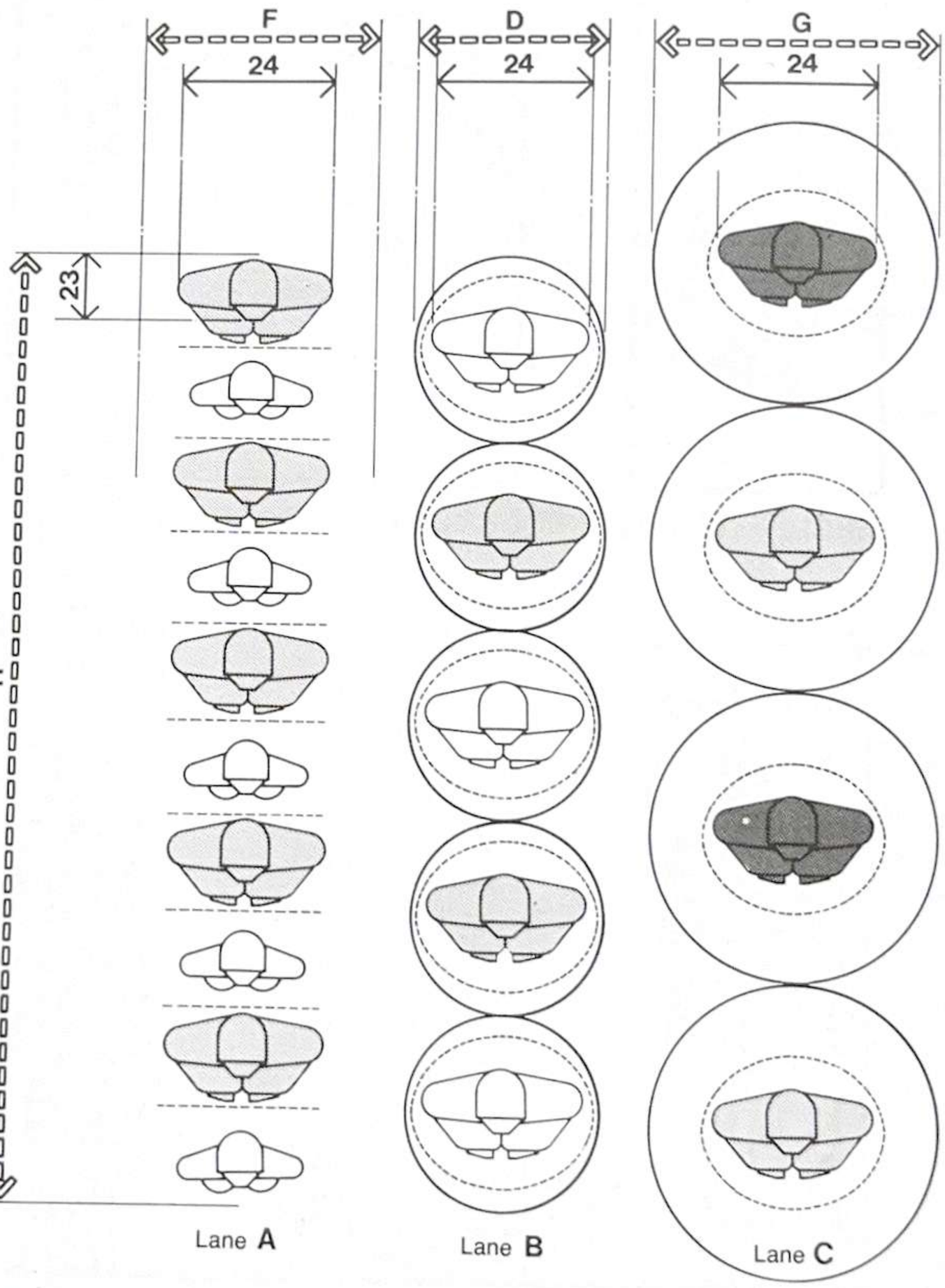
8.1 HORIZONTAL CIRCULATION SPACES

The purpose of the drawing at the top is to provide some idea of the physical relationship between human dimension and corridor width in terms of the number of lanes that can be accommodated. The row with three persons abreast is based on 95th percentile maximum clothed body breadth, while the row with four abreast is based on 5th percentile data. The corridor width was arbitrarily selected as 96 in, or 243.8 cm. The drawing should not be taken literally. The statistical likelihood of having the lineup of body sizes shown, at any single point in time, would be remote unless the space was originally intended to serve a specific user population of larger or smaller body size. Moreover, the 24-in, or 61-cm, lane with a 1.6-in clearance is obviously not intended as a standard.

The bottom drawing is intended to provide some insight into relative densities possible within a 120-in, or 308.4-cm, queue. Lane A shows as many people lined up as possible, with no regard for comfort or body contact. When an allowance for clothing is added to the maximum body breadth, the people in lane A would be pressed tightly together, violating all notions of personal space and comfort. Lanes B and C show the number of people that could be lined up, based on the densities of 3 and 7 sq ft, or .28 and .65 sq m per person, respectively.

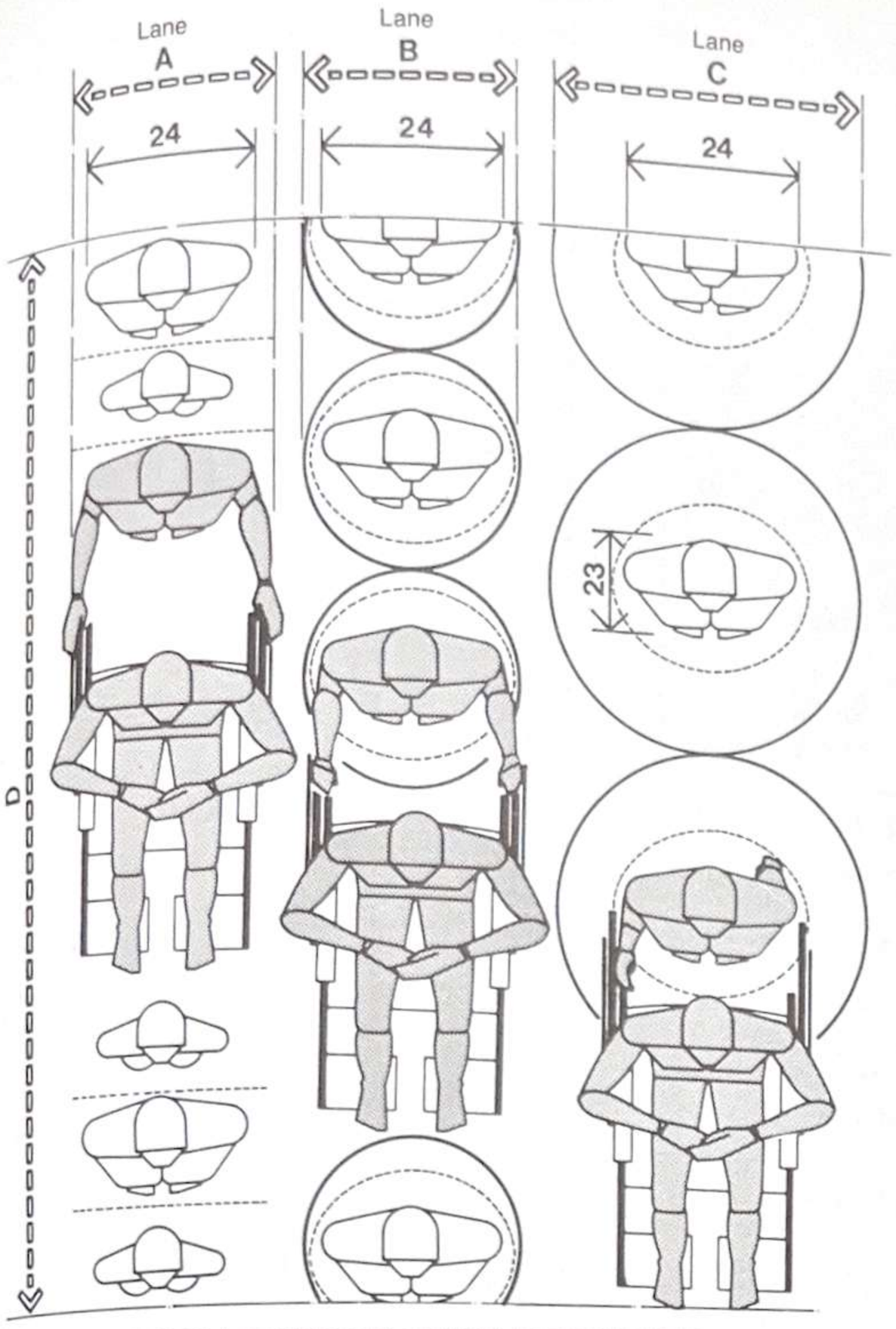


ACCOMMODATION OF SMALL AND LARGE USERS ABREAST IN A 96-IN (243.8-CM) CORRIDOR OR PASSAGE WIDTH

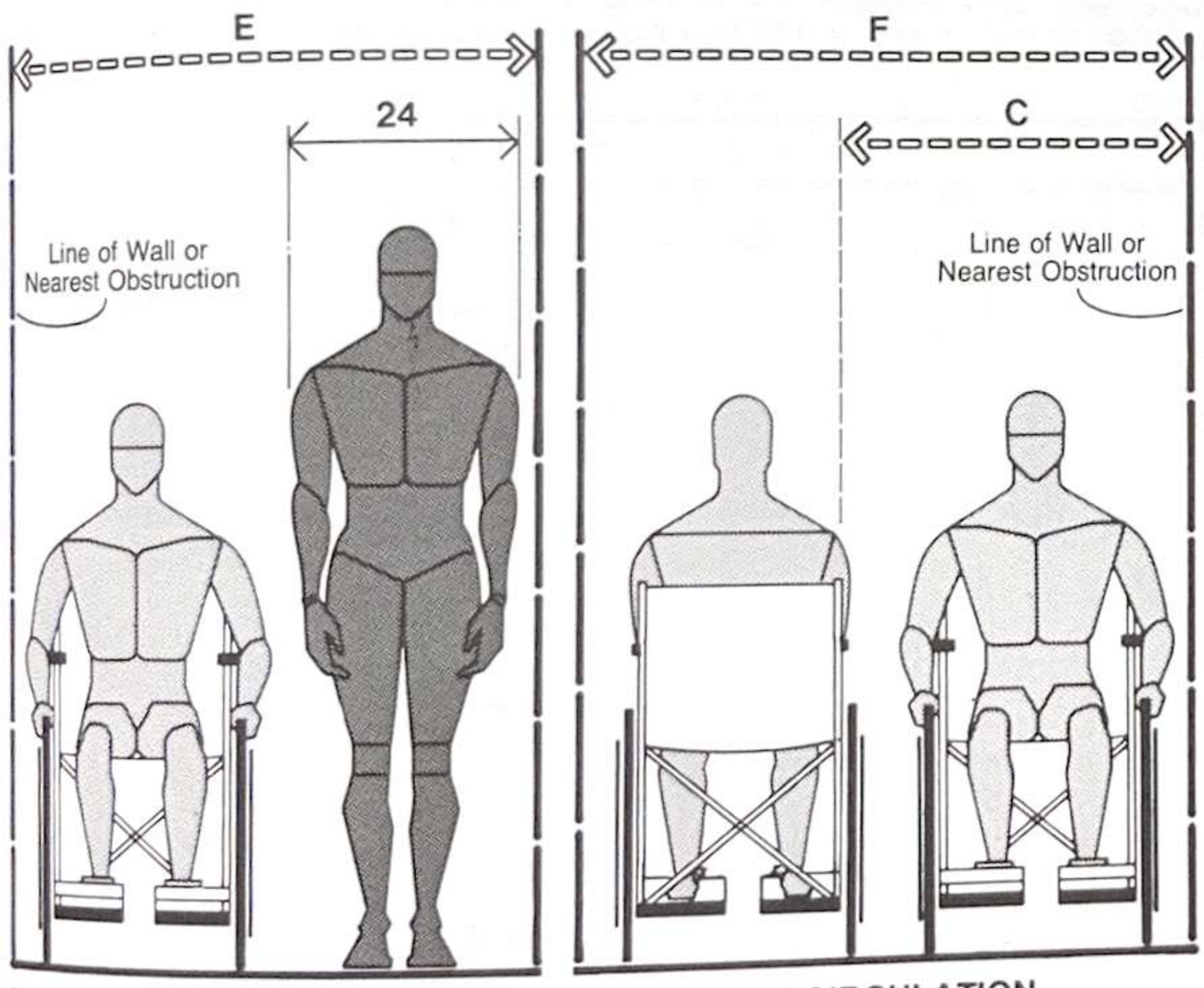


QUEUE LINES / COMPARATIVE DENSITIES

	in	cm
A	4.5	11.4
B	32	81.3
C	1.6	4.1
D	24	61.0
E	96	243.8
F	30	76.2
G	36	91.4
H	120	304.8



QUEUE LINES / COMPARATIVE DENSITIES INCLUDING WHEELCHAIR-BOUND



PARTIAL 2-WAY CIRCULATION

FULL 2-WAY CIRCULATION

WHEELCHAIR CIRCULATION / CORRIDORS AND PASSAGES

8.1 HORIZONTAL CIRCULATION SPACES

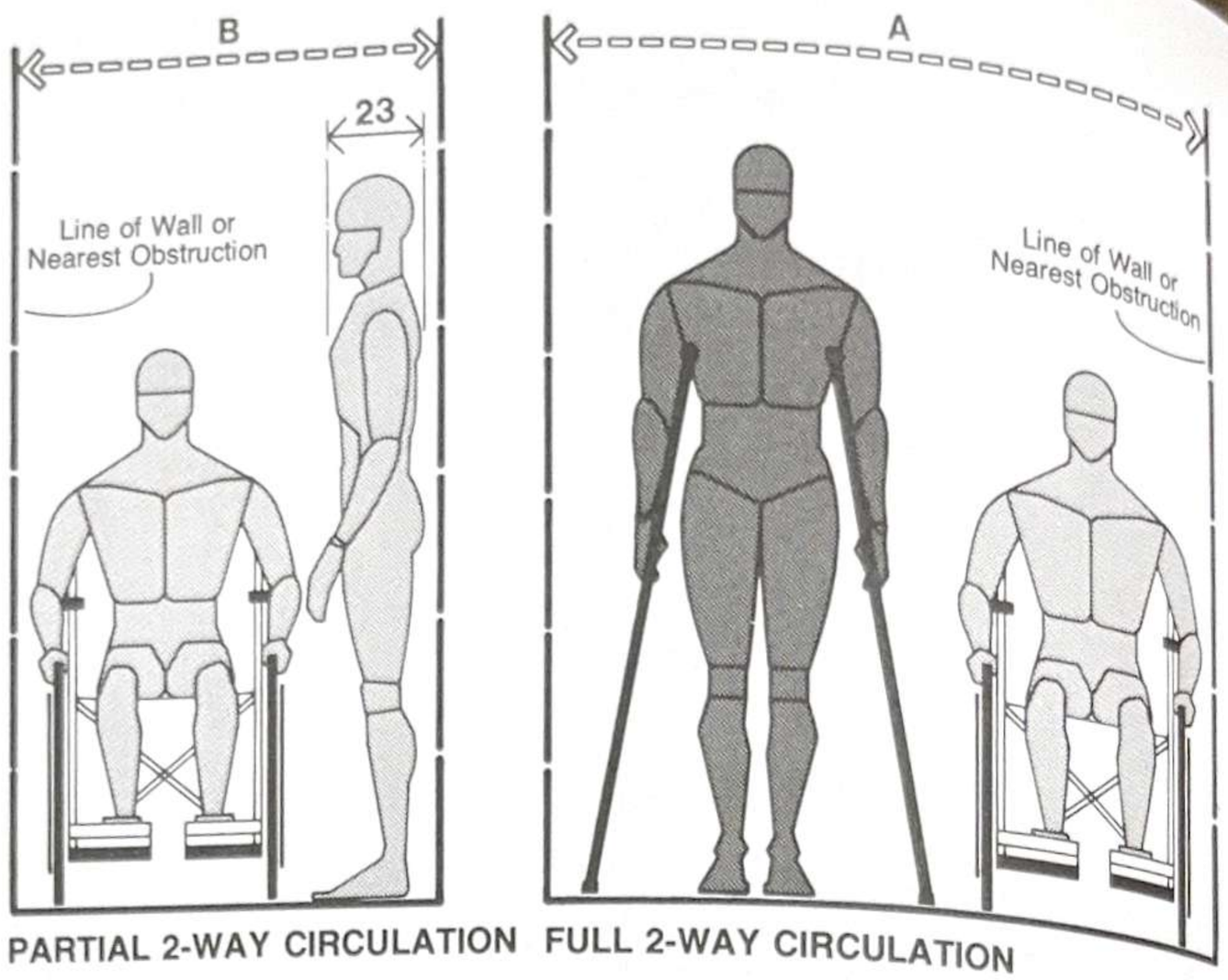
The drawing at the top indicates the impact of a wheelchair-bound person on the same queue shown on the preceding page. The bottom drawing indicates corridor width clearances necessary to accommodate wheelchair circulation. Full two-way passage requires 60 in, or 152.4 cm, to allow two wheelchairs to pass side by side. Clearance for a single wheelchair is 36 in, or 91.4 cm. A 54-in, or 137.2-cm, corridor will allow an able-bodied individual to walk along side or pass a wheelchair-bound person. Ideally, rest stops should be provided where corridor lengths are particularly long. These may be in the form of properly designed alcoves along the circulation path; rest room lounges or reception areas may be substituted if reasonably located. Maximum distance between rest room stops should be about 100 ft, or 30.5 m. Provisions for wheelchair turning should also be considered. A full 360° turn can be negotiated within a 60-in, or 152.4-cm, diameter circle.

	in	cm
A	30	76.2
B	24	61.0
C	36	91.4
D	120	304.8
E	54	137.2
F	60	152.4

Printed in China

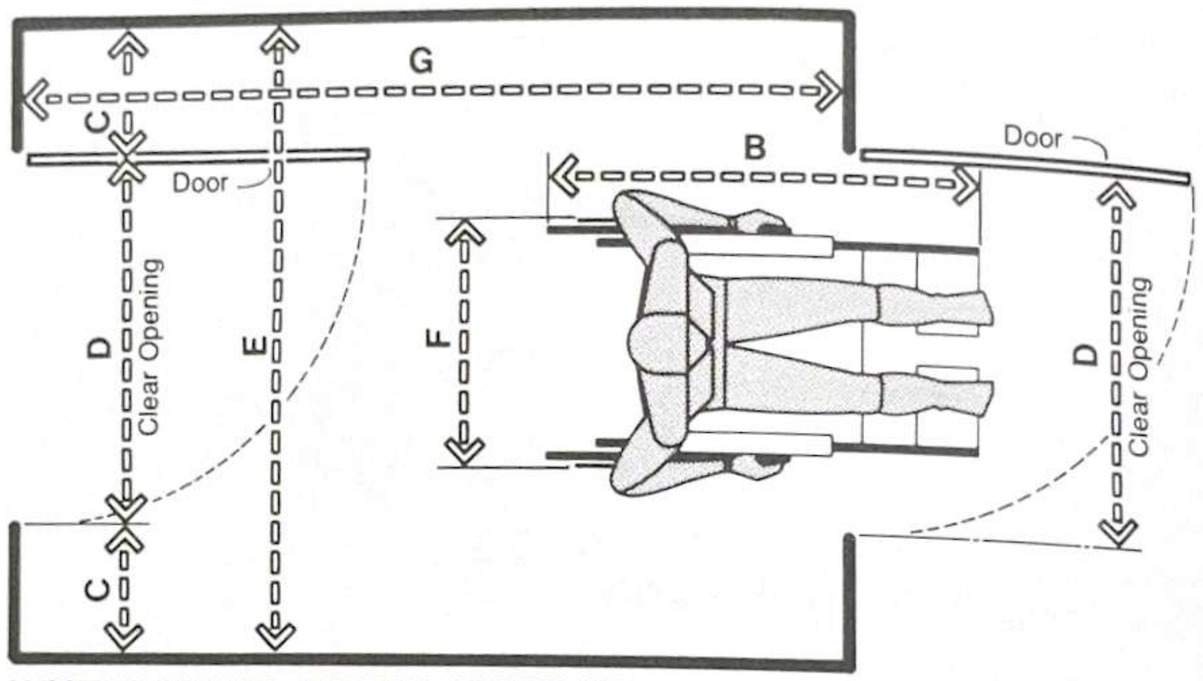
8.1 HORIZONTAL CIRCULATION SPACES

The top drawing indicates that a 60-in, or 152.4-cm, clearance is necessary for a person on crutches to walk along side or pass a person in a wheelchair. A 42-in, or 106.7-cm, clearance is needed to accommodate a person standing sideways, while allowing a wheelchair-bound person to pass. The other two drawings indicate the clearances necessary to accommodate a wheelchair in spaces where a series of two doors are involved. One drawing illustrates a situation where the two doors are in a row and the other where the doors are at right angles. A clearance of 84 in, or 213.4 cm, is necessary to allow the wheelchair to clear the first door as it swings shut. Since the length of the wheelchair is 42 in, or 106.7 cm, the 84-in dimension would allow for a door as wide as 36 in, or 91.4 cm, and an additional clearance of 6 in, or 15.2 cm, to spare. The 12-in, or 30.5-cm, minimum clearance on either side of the door allows enough maneuvering room for the wheelchair to approach the door at a slight angle and a person to grasp the door knob or pull and then back away. This is helpful when approaching the door from the in-swing side. When the doors are located at right angles to each other, it is essential that adequate space be provided to avoid interference between the two doors.

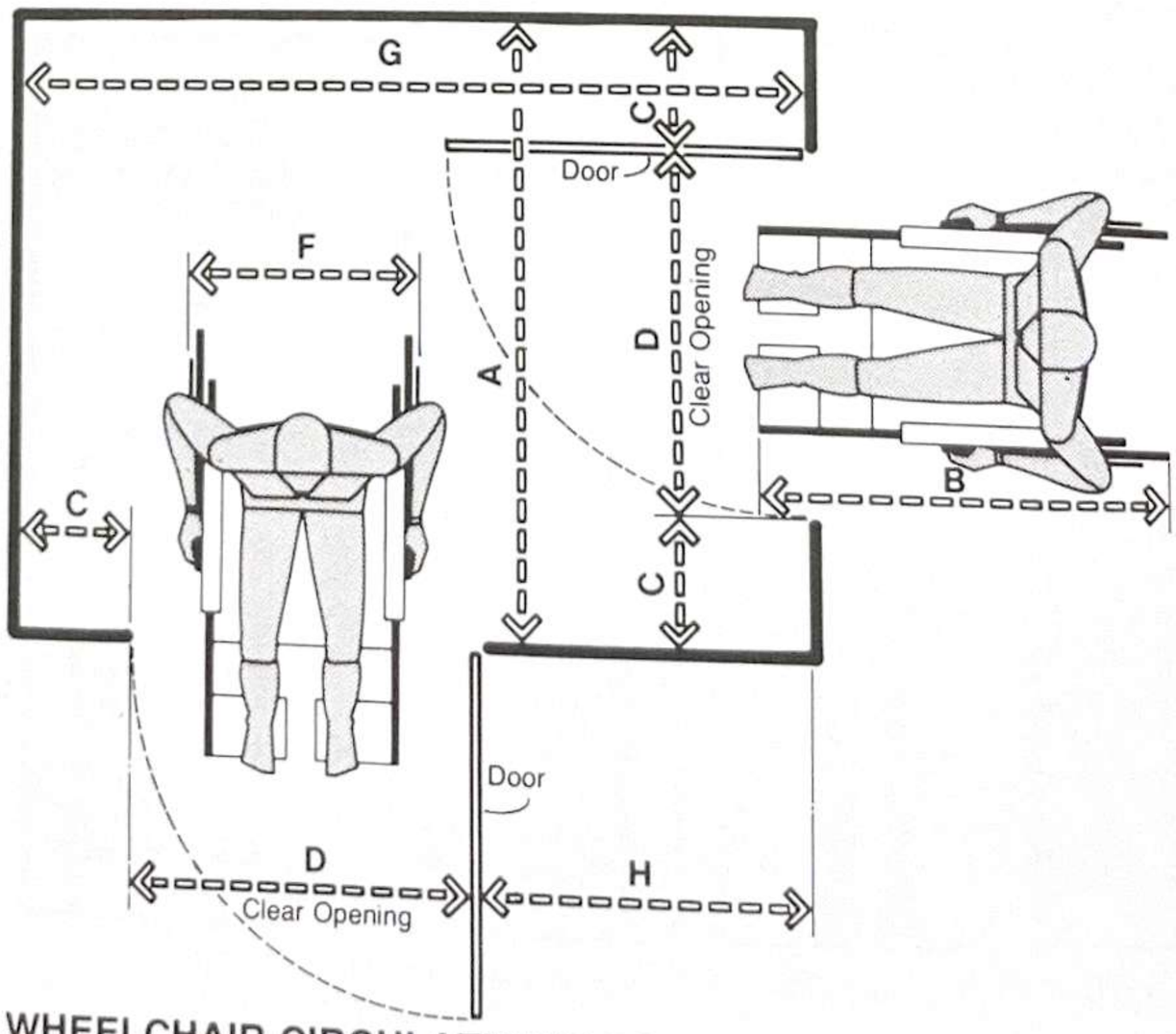


PARTIAL 2-WAY CIRCULATION FULL 2-WAY CIRCULATION

WHEELCHAIR CIRCULATION/CORRIDORS AND PASSAGES



WHEELCHAIR CIRCULATION / DOORS IN ALIGNMENT



WHEELCHAIR CIRCULATION/DOORS AT RIGHT ANGLES

	in	cm
A	60	152.4
B	42	106.7
C	12 min.	30.5 min.
D	32	81.3
E	56 min.	142.2 min.
F	25	63.5
G	84	213.4
H	36 min.	91.4 min.

8.2 VERTICAL CIRCULATION SPACES

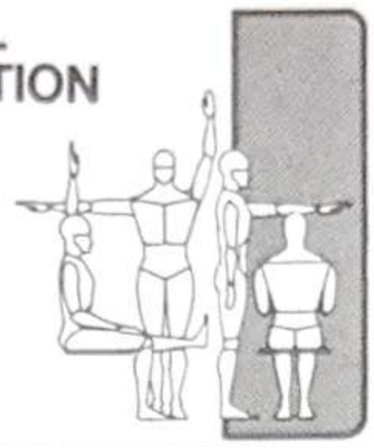


TABLE	ESCALATOR	STAIR	RAMP	ELEVATOR	ACTIVITIES
					ANTHROPOMETRIC DATA
1A,2B		●			1 STATURE
1B,3C		◑		◑	2 EYE HEIGHT
1F,3G				○	6 EYE HEIGHT SITTING
1W,6B				●	23 MAXIMUM BODY DEPTH
1X,6A	●	●	●	●	24 MAXIMUM BODY BREADTH

No public space can function without adequate vertical circulation systems. If these systems are not designed with human body size in mind, however, the efficiency and use of these systems are diminished. Moreover, the personal safety of the user is endangered. Nowhere is this more critical than in stair design. Both the width of the stair and the tread/riser relationship must reflect the human dimension. For stair width, most prevailing standards and guidelines directly or indirectly employ a unit of measurement of 22 in, or 55.9 cm, which purportedly represents the width of a so-called average person, a basic contention with which the authors disagree and which will be explored in the drawings and text on the following pages. This 22-in increment, however, is used as a basis for establishing lane width and has been in use and unchallenged for at least 25 years.

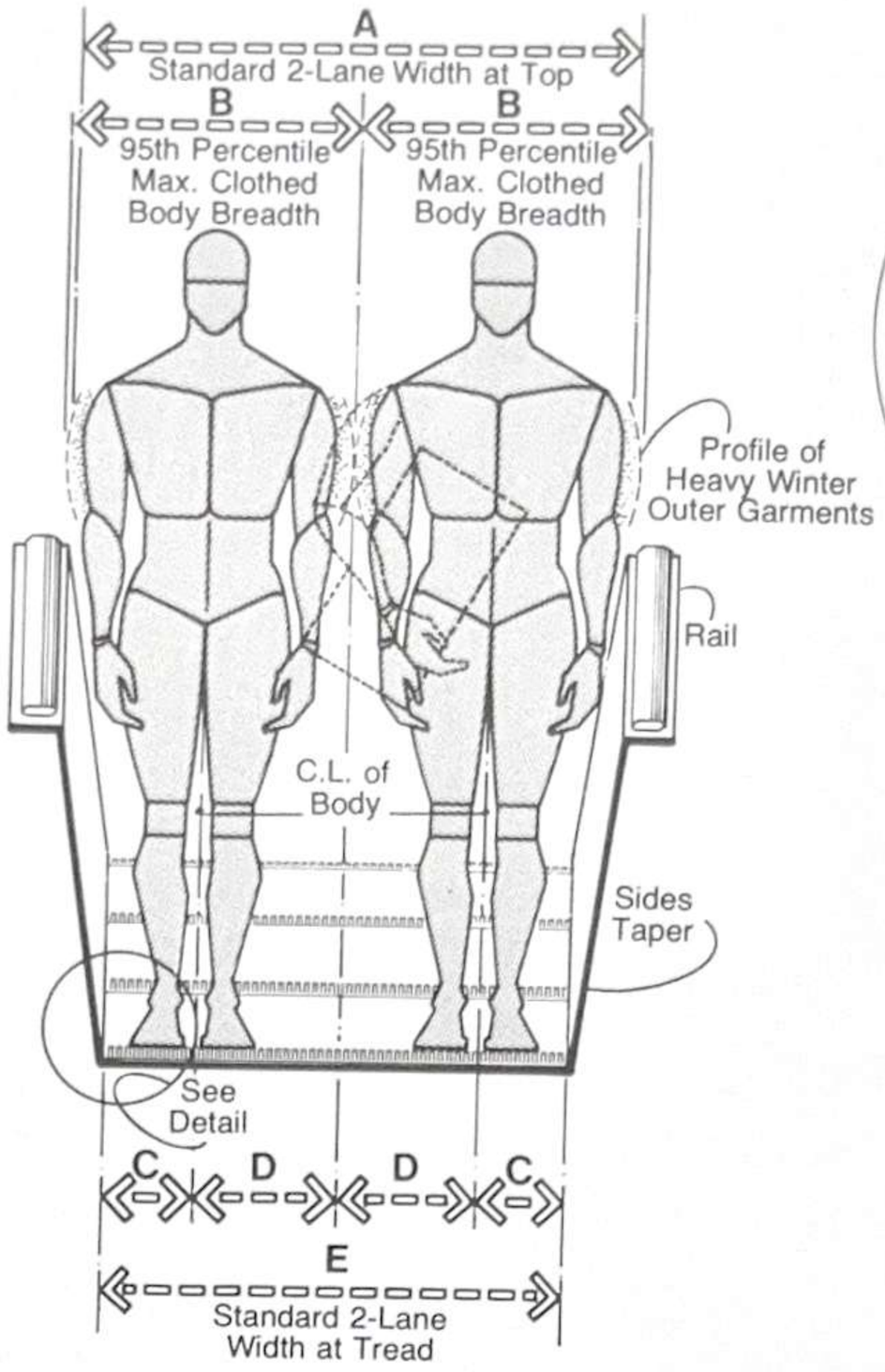
Tread/riser relationships are also based on assorted rules of thumb and formulas, many of which are in conflict with each other. One such formula, over 400 years old, is incorporated into the building code of the city of New York. That these formulas produce some kind of generally reasonable design is not disputed. What should be questioned is the quality of that design. How does a 9.5-in, or 24.1-cm, tread, for example, accommodate a maximum shod foot length of 14 in, or 35.6 cm? How much contact surface does the design provide? How much human energy is consumed in ascending the stair? What percentage of the user population is accommodated? If the stair is to be used to evacuate the building in the event of fire, can we afford to accommodate any less than 100 percent of the users? Does the tread/riser relationship reflect the needs of elderly people? These questions must be answered if designers are to be responsive to the human factors involved. There is also no doubt that proper tread/riser proportion involves other considerations as well, such as human gait, sensory perception, age, sex. A "perfect" solution may not be possible in view of the nature of the problem, but something more than a rule of thumb is needed. The drawings on the following pages examine some of these conditions and suggest clearances and other dimensional data responsive to human dimension and body size and useful in establishing preliminary design assumptions. The matrix above indicates some of the more relevant anthropometric measurements to consider.

8.2 VERTICAL CIRCULATION SPACES

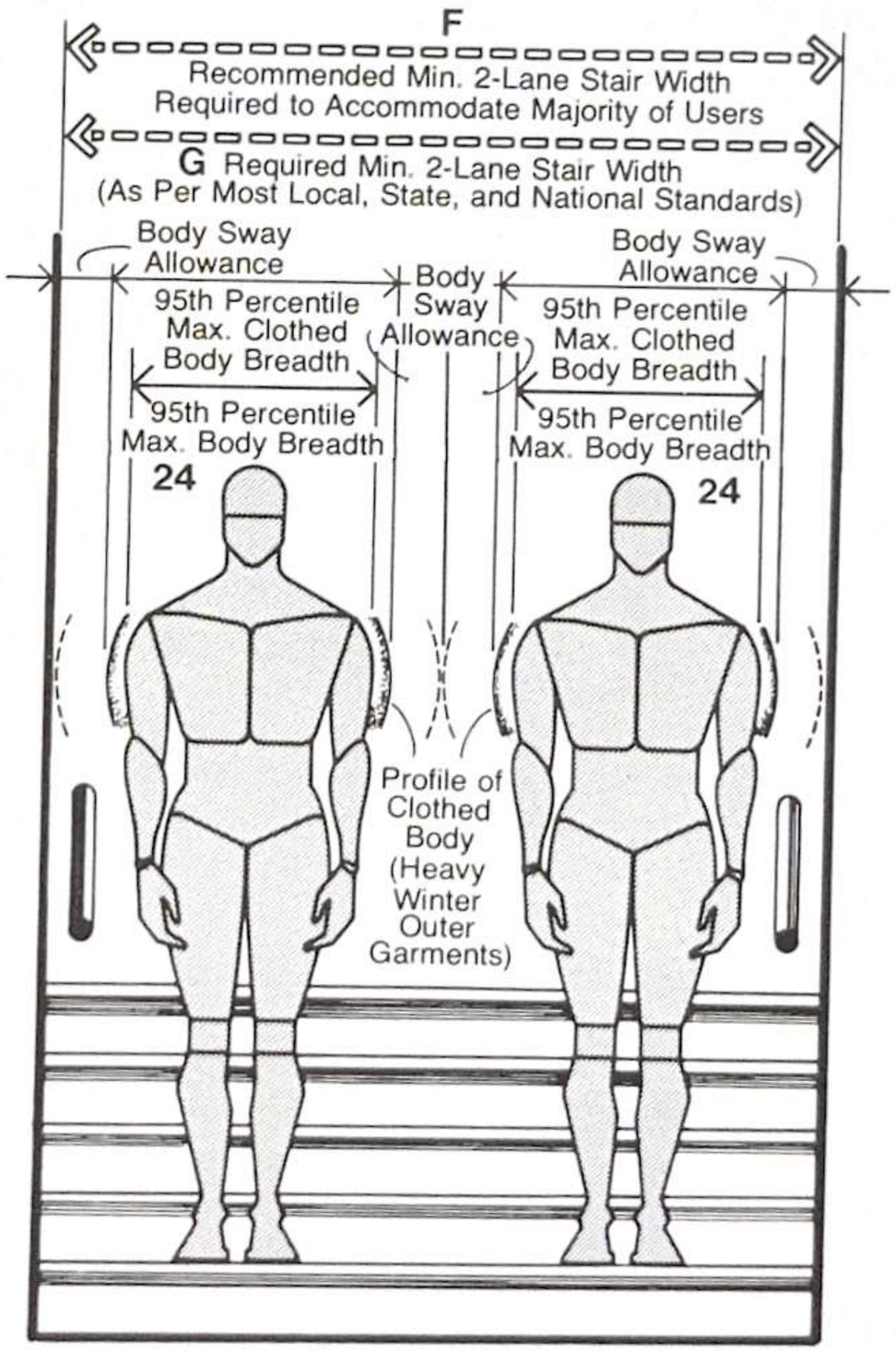
The drawing of the 48-in, or 121.9-cm, two-lane escalator is intended to illustrate that 48 in is inadequate to comfortably accommodate larger-sized people on the same tread. Moreover, the 40-in, or 101.6-cm, clearance at the bottom limits the user's stance, thereby reducing body stability. Stair motion, body contact, and lack of stability, taken together, present a safety hazard. This may account for the fact that the presence of two people on the same tread is not a very frequent occurrence.

The authors contend that the standard 44-in, or 117.7-cm, stair width, based on two 22-in, or 55.9-cm, body increments, will not accommodate those of larger body size. The argument against the 22-in increment is presented in the text related to the first drawing in Section 8.1.

Rail clearance should accommodate the hand thickness of the larger user and handrail size, the inside grip diameter of the smaller user. Adding glove thickness to the data shown in the drawing, a 2-in, or 5.1-cm, clearance and a 1.5-in, or 3.8-cm, rail diameter will accommodate most people.

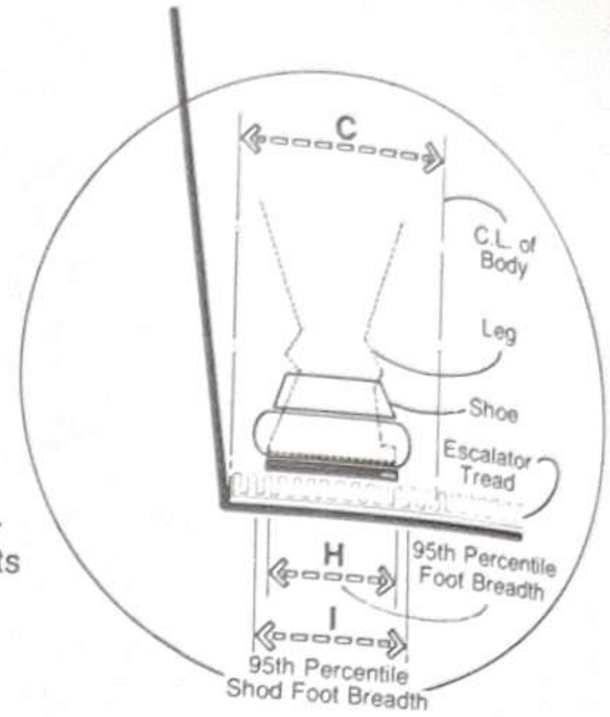


ESCALATORS

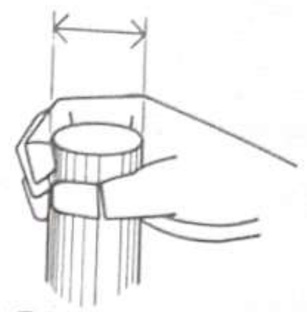


STAIRS / EXISTING AND RECOMMENDED 2-LANE WIDTH

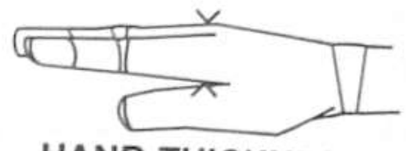
	in	cm
A	48	121.9
B	25.8	65.5
C	7.1	18.0
D	12.9	32.8
E	40	101.6
F	68	172.7
G	44	111.8
H	4.2	10.7
I	4.9	12.4
J	2 min.	5.1 min.
K	1.5	3.8
L	3.5 max.	8.9 max.
M	30–34	76.2–86.4
N	1.5 min.	3.8 min.



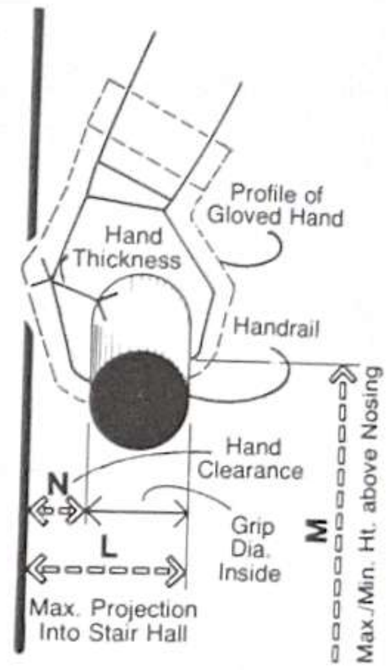
DETAIL



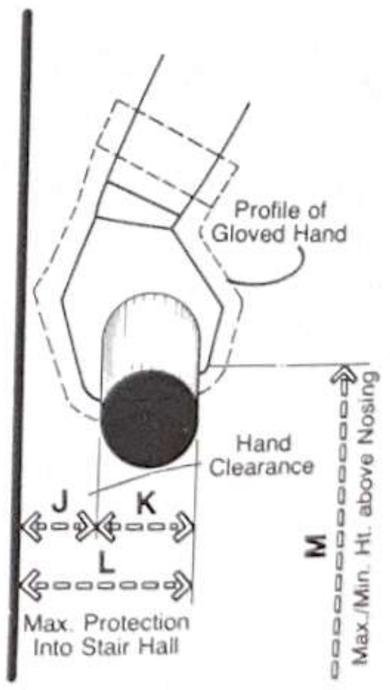
GRIP DIAMETER INSIDE



HAND THICKNESS

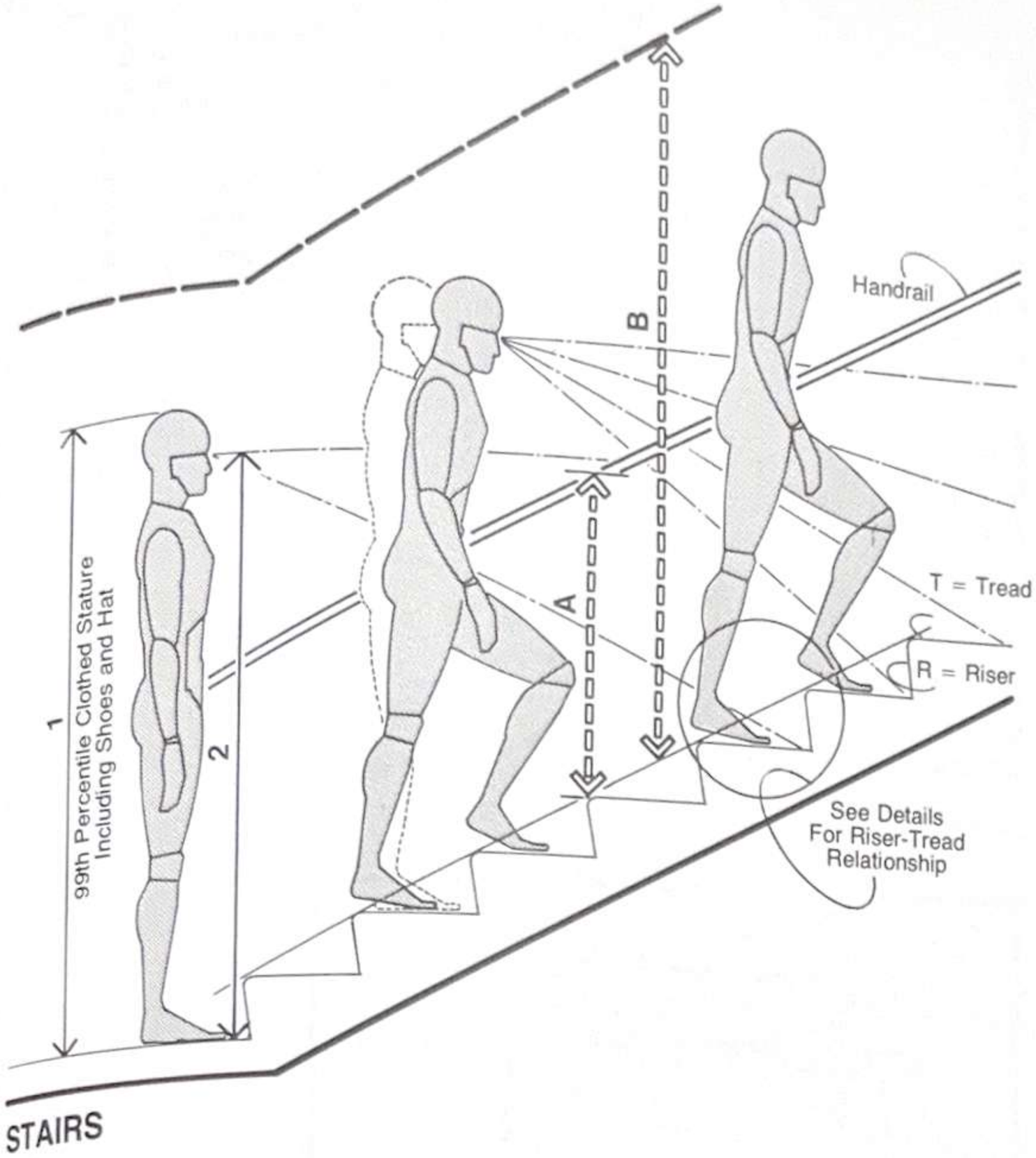


HANDRAILS/ ANTHROPOMETRIC STUDY OF PREVAILING STANDARDS



HANDRAILS/ RECOMMENDED DESIGN BY AUTHORS

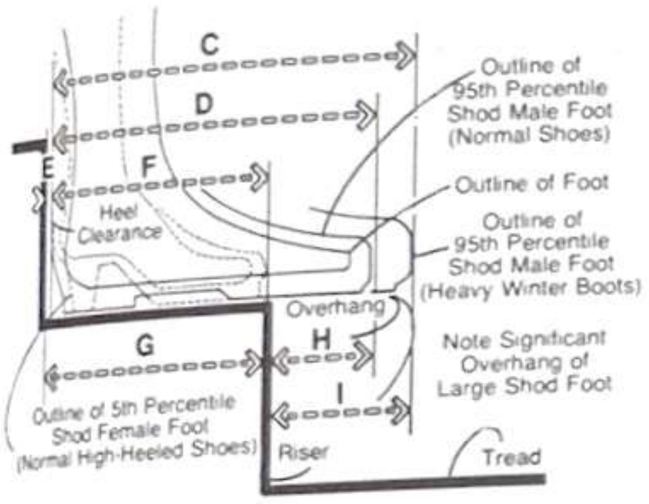
8.2 VERTICAL CIRCULATION SPACES



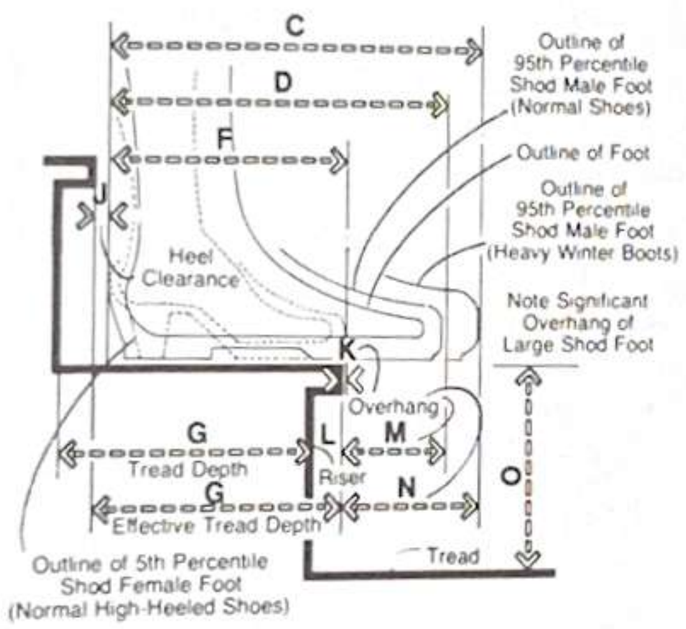
STAIRS

The top drawing shows some basic dimensional data and suggests the viewing zones involved. Although the stair is nearly as old as the architectural discipline itself, relatively little research has been done and most code requirements are based on rules of thumb, some dating back to the 17th century. The tread-riser relationship is the most important consideration here.

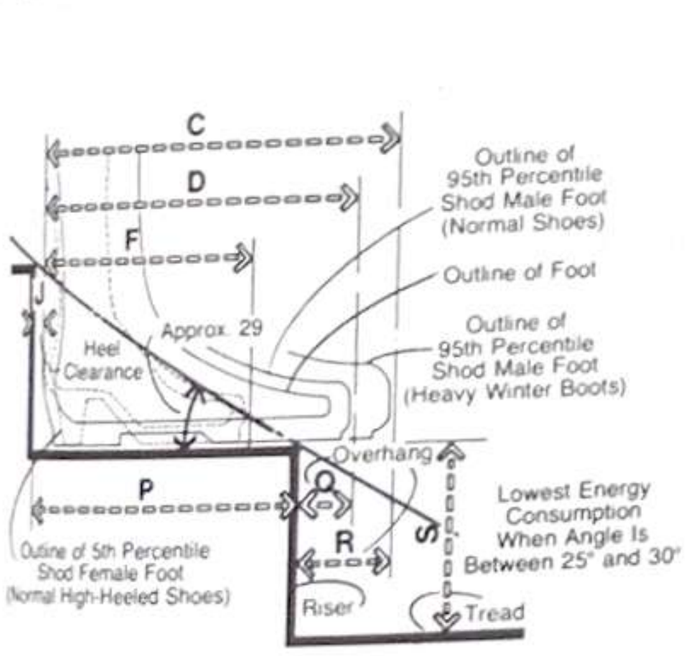
The bottom drawings show the anthropometric relationship between shod foot length and tread depth. Ninety-five percent of users with heavy winter boots have a shod foot length of about 9 in, or 22.9 cm, or less. The 9.5-in, or 24.1-cm, tread presently in common use allows comfortable tread contact for only 5 percent of the users, while the foot of the larger user overhangs the tread by more than 5 in, or 12.7 cm—certainly a cause for concern, especially for old and physically disabled people.



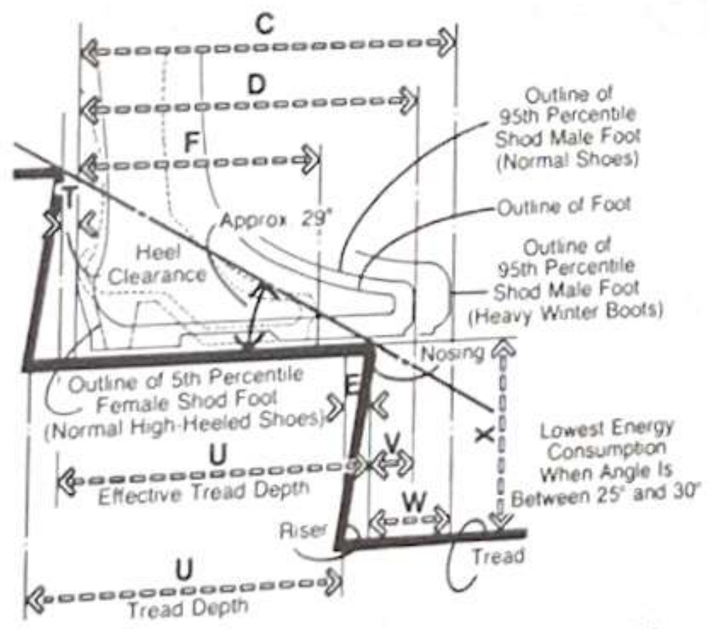
DETAIL OF TREAD-RISER RELATIONSHIP/ SCHEMATIC ANTHROPOMETRIC STUDY



DETAIL OF TREAD-RISER RELATIONSHIP/ TYPICAL DESIGN IN COMMON USE



TREAD-RISER RELATIONSHIP/ RECOMMENDED PROPORTIONS (LEHMAN, 1962)



DETAIL OF TREAD-RISER RELATIONSHIP/ RECOMMENDED PROPORTIONS BY AUTHORS WHERE STRUCTURAL AND SPACE CONDITIONS PERMIT

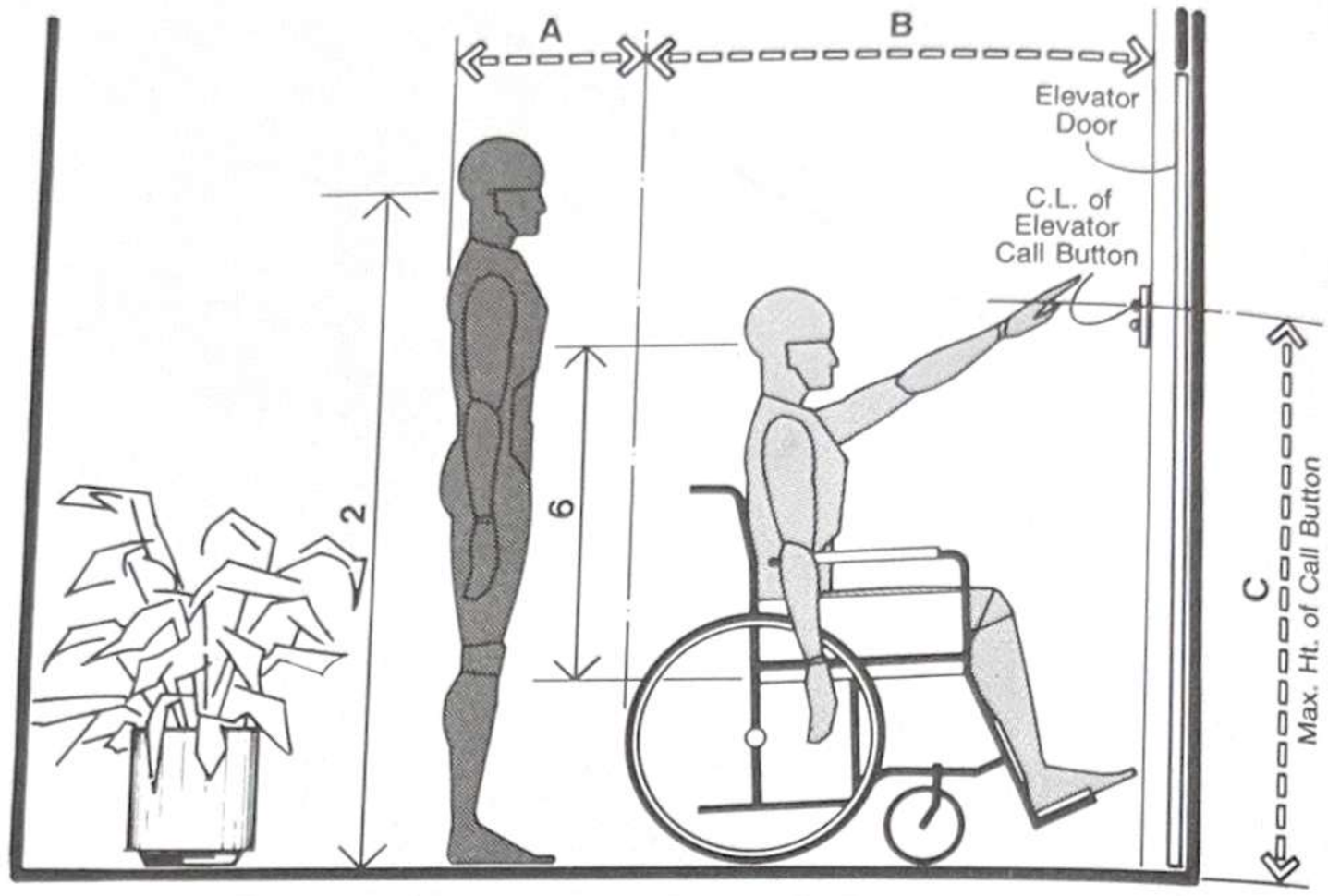
	in	cm
A	30–34	76.2–86.4
B	84 min.	213.4 min.
C	14.3	36.3
D	12.9	32.8
E	0.3	0.6
F	9.1	23.1
G	9.5	24.1
H	3.7	9.3
I	5	12.7
J	0.5	1.3
K	0.1	0.3
L	1.3	3.2
M	3.9	9.9
N	5.3	13.5
O	7.5	19.1
P	11.4	29.0
Q	2	5.1
R	3.4	8.6
S	6.7	17.0
T	0.5–1	1.3–2.5
U	11.8	29.8
V	1.6–2.1	4.1–5.3
W	3–3.5	7.6–8.9
X	6.8	17.1

DETAILS OF TREAD-RISER RELATIONSHIP

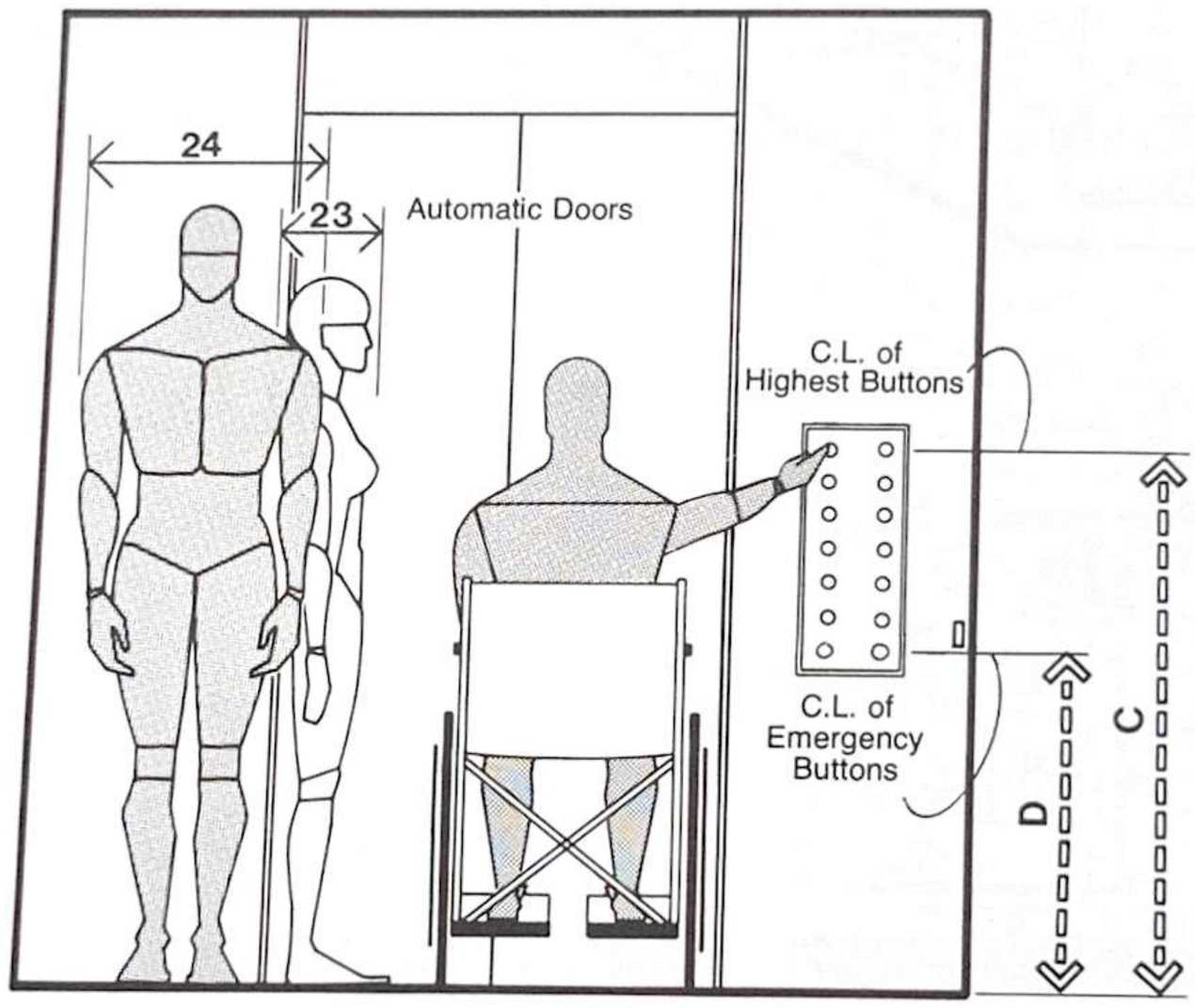
8.2 VERTICAL CIRCULATION SPACES

Vertical circulation systems must be responsive to the needs of people confined to wheelchairs as well as to those of able-bodied people. Corridor and lobby call buttons should be located 54 in, or 137.2 cm, above the floor. Emergency controls should be arranged so that the lowest button is a minimum of 30 in, or 76.2 cm, above the cab floor and the highest button a maximum of 48 in, or 121.9 cm, above the cab floor. Emergency buttons should be grouped together at the bottom of the panel. The center line of a telephone should be a maximum of 48 in above the cab floor and the height at the top of the handrail should be located between 32 and 34 in, or 81.3 and 86.4 cm, above the cab floor.

Ramps are also an important factor in providing accessibility of buildings to handicapped people. Most regulations and guidelines insist on a maximum gradient of one unit of height for every twelve units of length and a maximum horizontal distance of 30 ft, or 9 m, without a horizontal landing of at least 42 in, or 106.7 cm. Landings should be provided at all changes in ramp direction and at entrances and exits. Platform lengths should provide at least 42-in clearance from any door swing into the ramp. Where the door does not swing into the ramp, the platform should extend a minimum of 24 in, or 61 cm, past the latch side of the door.

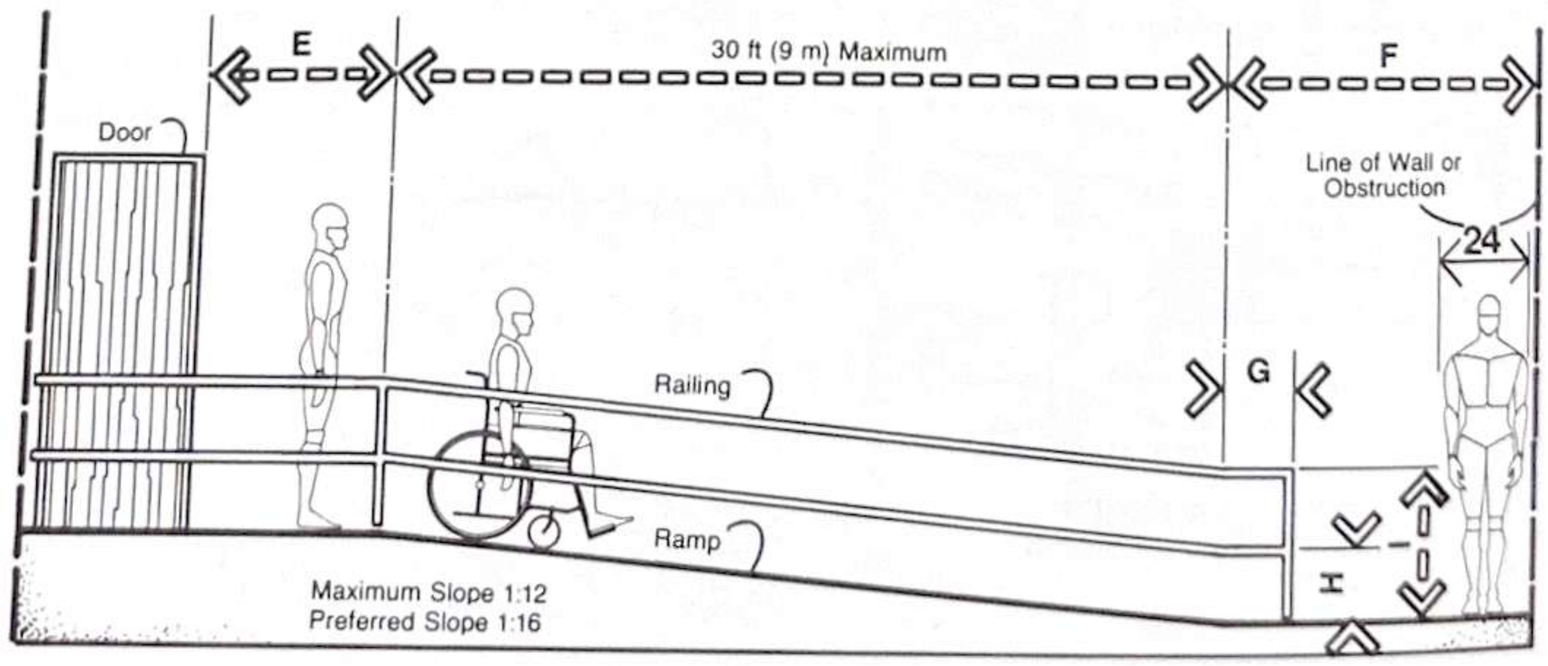


ELEVATORS / LOBBY



ELEVATORS / CAB INTERIOR

	in	cm
A	18	45.7
B	48 min.	121.9 min.
C	54 max.	137.2 max.
D	30	76.2
E	42 min.	106.7 min.
F	72 min.	182.9 min.
G	12–18	30.5–45.7
H	18–20	45.7–50.8
I	33–34	83.8–86.4



ACCESS RAMP

8.3 PUBLIC BATHROOMS

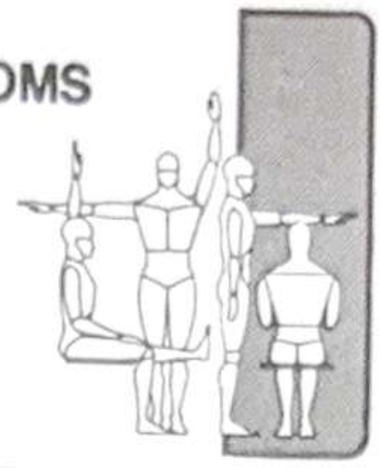


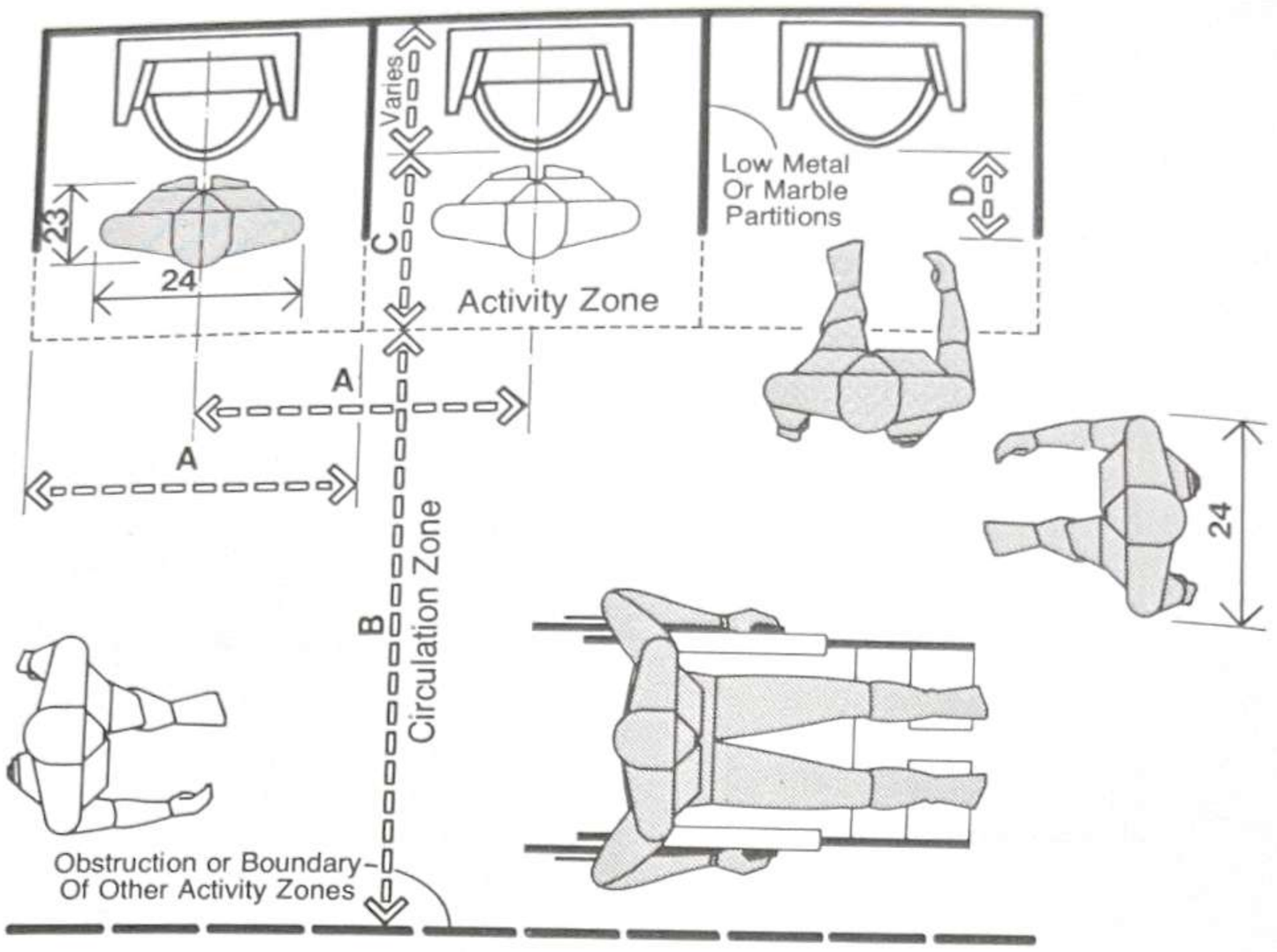
TABLE	LAVATORY	URINAL	WATERCLOSET	CIRCULATION	ACTIVITIES
					ANTHROPOMETRIC DATA
1A,2B	◔				1 STATURE
1B,3C	●		●	●	2 EYE HEIGHT
1F,3G	○				6 EYE HEIGHT SITTING
1V,4D	○				22 THUMB TIP REACH
1W,6B	●	●			23 MAXIMUM BODY DEPTH
1X,6A	●	●		●	24 MAXIMUM BODY BREADTH

The term "public" toilet facility is to a large degree generic since it is quite possible and proper to create subclassifications depending on the user population it is intended to serve. A public facility located in an air, bus, or rail terminal, for example, would serve a transient user as opposed to a similar facility provided for the convenience of the workers in a large midtown office building. These facilities may have much and at the same time very little in common. To varying degrees they both have peak periods of use. The anthropometric considerations, particularly during these peak periods, are also quite similar. Since the intent is to focus on human dimension as it relates to interior space, no attempt has been made to establish a classification system or to comment on the inherent design of the fixtures themselves.

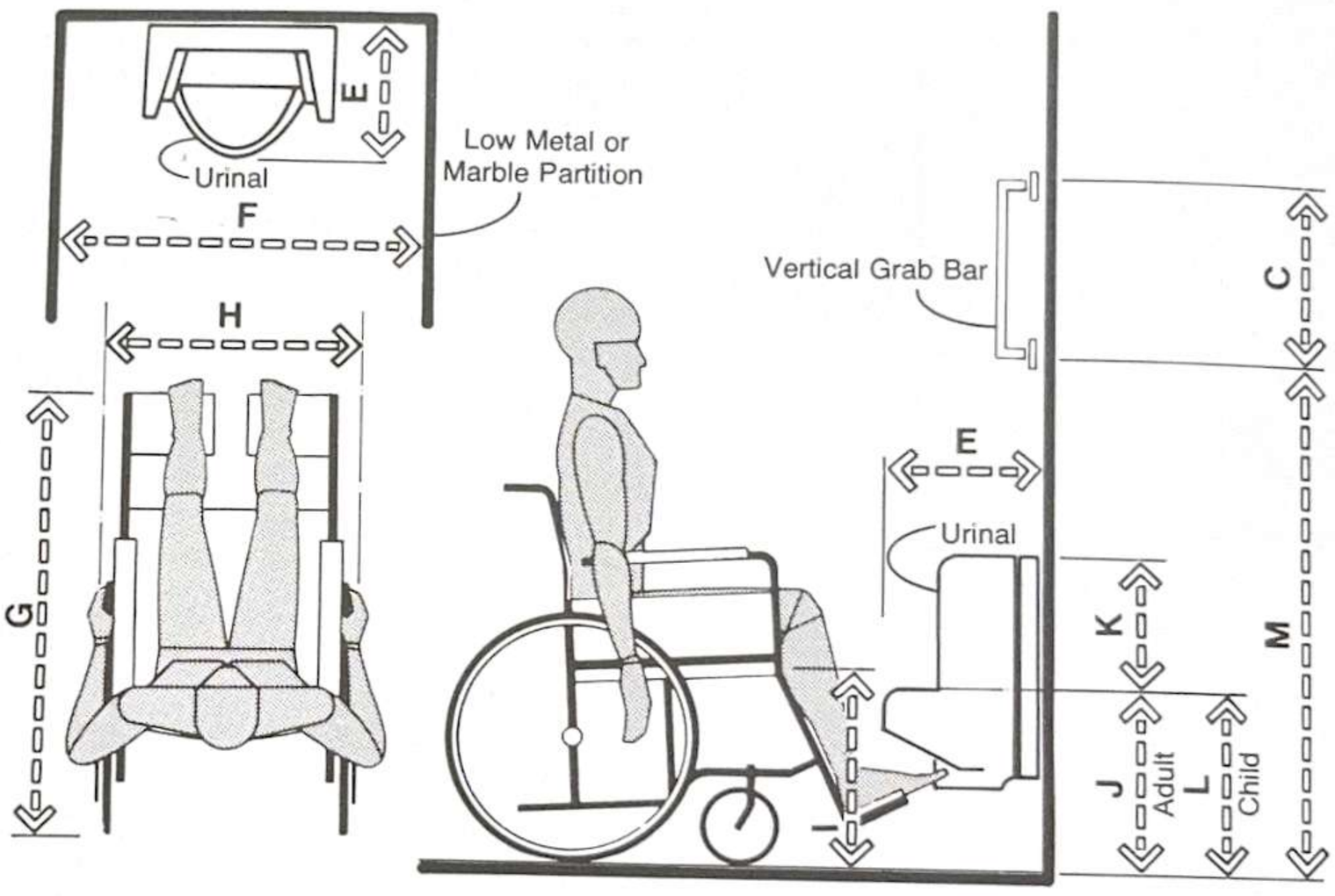
What is painfully obvious in the drawings on the following pages is that most public toilet facility designs appear to be totally insensitive to human dimension and body size. Most designs crowd the designated number of fixtures required by local agencies in the least amount of floor space possible. The fact is that the spacing of fixtures, particularly urinals (19 and 21 in, or 48.3 and 53.6 cm, on center is not uncommon), does not accommodate the majority of users. Published anthropometric data, for example, indicates that only 5 percent of a sample population measured has a maximum body breadth dimension of 18.8 in, or 47. 8 cm, or less. When a clothing allowance is added, it becomes obvious that a 19- or a 21-in, or a 48.3- or a 53.6-cm, spacing would make it almost impossible for people to use the urinals without coming into body contact with each other. The same type of situation exists with regard to lavatory fixtures. When one considers the hidden dimensions, body buffer zones, privacy factor, such spacing becomes totally unacceptable. For this reason it is not uncommon in public bathrooms to observe situations of extreme crowding and congestion with people queued up waiting to use the facilities while at the same time every other fixture may be unoccupied. The drawings on the following pages examine these conditions and such clearances and other dimensional data more responsive to human body size and dimension, while the matrix above suggests some of the more important anthropometric measurements to consider in the design of public bathrooms.

8.3 PUBLIC BATHROOMS

Stall urinals are available for battery installations on 21-in, or 53.3-cm, centers. The authors contend that such spacing will not properly accommodate the majority of users. The larger-sized person has a maximum clothed body breadth dimension of almost 26 in, or 66 cm. Postures assumed while urinating, in addition to the space taken up by partially opened garments, will increase this dimension even more. Given the anthropometric realities and consideration of personal space, a 32-in, or 81.3-cm, spacing is more responsive to human factors. The stall partition should extend 8 to 10 in, or 20.3 to 25.4 cm, beyond the face of the urinal, and an activity zone of 18 in, or 45.7 cm, in front of the fixture should be assumed. A circulation zone of 54 in, or 137.2 cm, will allow for pedestrian and wheelchair traffic. Urinal stalls for wheelchair users should be a minimum of 36 in, or 91.4 cm, wide for proper access. Minimum toilet stall dimensions required for a front transfer approach by the wheelchair user are 42 by 72 in, or 106.7 by 182.9 cm. A wheelchair clearance zone should be provided in front of the stall.

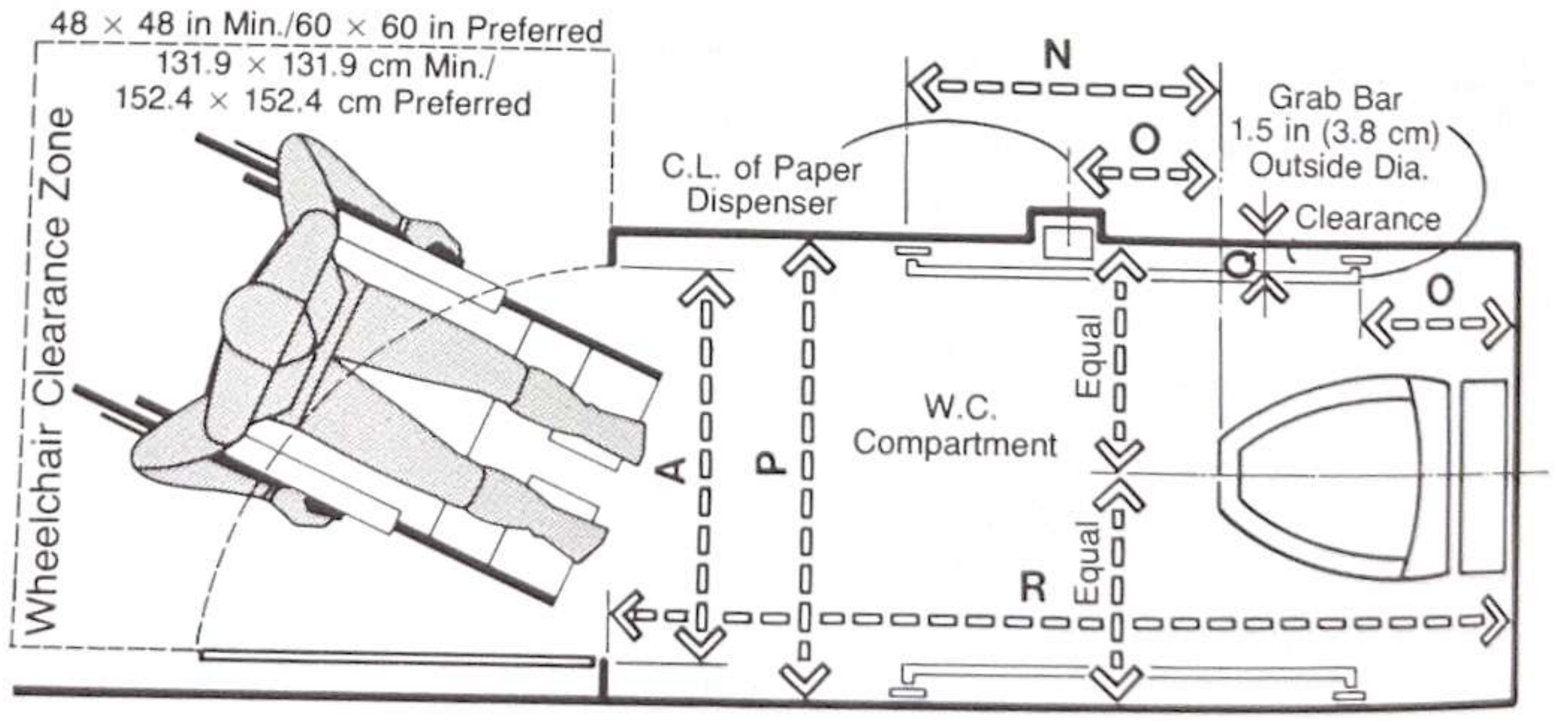


URINAL LAYOUT



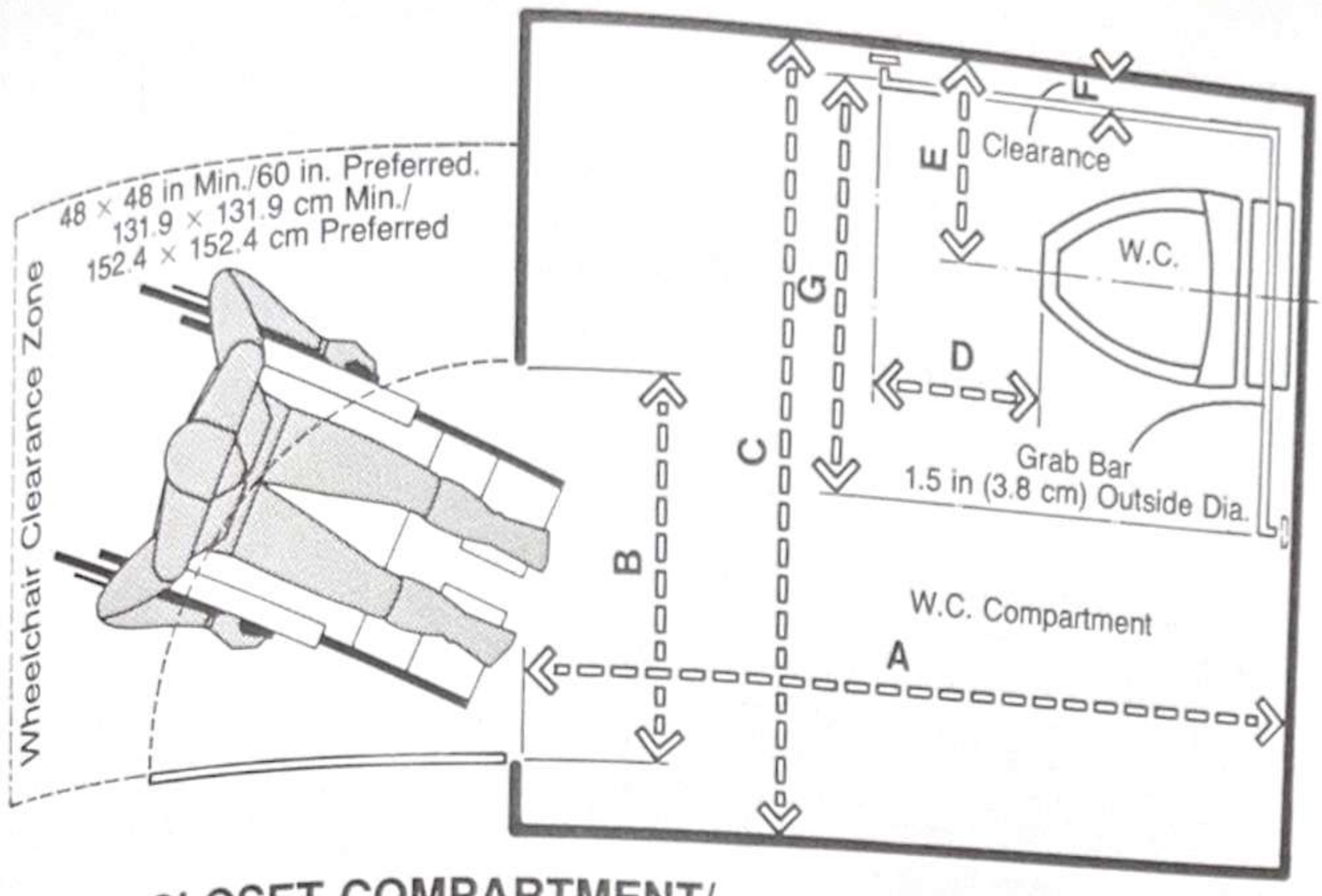
URINAL LAYOUT / CHAIRBOUND USER

	in	cm
A	32	81.3
B	54	137.2
C	18	45.7
D	8–10	20.3–25.4
E	14 min.	35.6 min.
F	36 min.	91.4 min.
G	42	106.7
H	25	63.5
I	19	48.3
J	17 max.	43.2 max.
K	12 min.	30.5 min.
L	14 max.	35.6 max.
M	48	121.9
N	18 min.	45.7 min.
O	12	30.5
P	42 min.	106.7 min.
Q	1.5 min.	3.8 min.
R	72 min.	182.9 min.



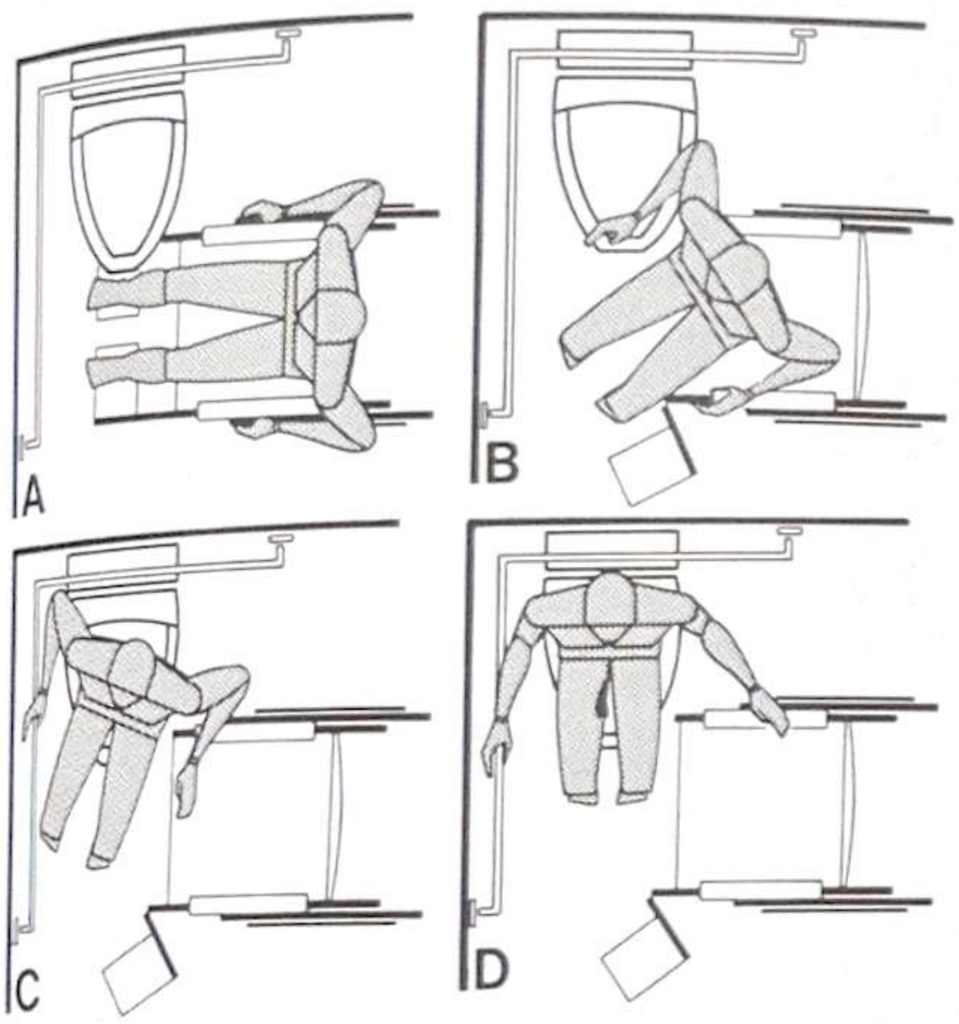
W.C. COMPARTMENT / FRONT TRANSFER APPROACH

8.3 PUBLIC BATHROOMS



Rather than the front transfer approach discussed on the preceding page, a more comfortable access to the W.C. for the wheelchair user is the side approach transfer. The top drawing shows the minimum compartment dimensions for such a transfer: 66 by 72 in, or 167.6 by 182.9 cm. To appreciate the problems faced by those confined to a wheelchair in gaining access to rest room facilities, it is necessary to understand something of the transfer process. The center drawing attempts to break down that process into four basic movements; techniques will vary from user to user, but the process is essentially as illustrated. The bottom drawing shows some of the basic heights and clearances to be considered in a conventional W.C. compartment. Note that different heights for the W.C. are suggested in response to the anthropometric requirements of elderly people and children.

WATER CLOSET COMPARTMENT/ SIDE APPROACH TRANSFER



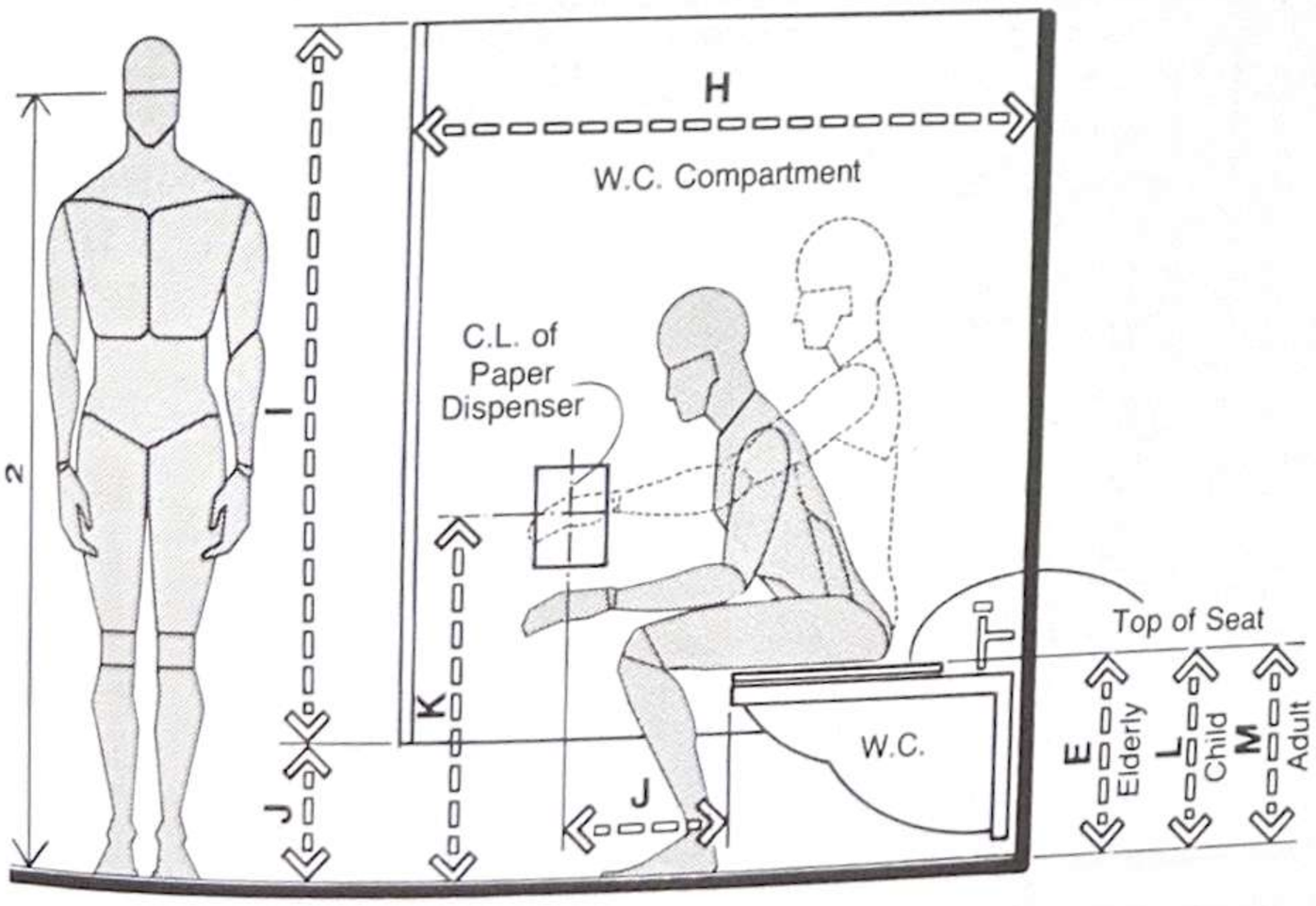
A User Approaches W.C. From the Side

B Chair Armrest Is Removed and Footrest Is Swung to Side for Clearance. For Stability and Leverage, One Hand Is Placed on W.C. Seat or Grab Bar and the Other on Chair. Transfer Movement Begins

C User Lifts, Slides, and Rotates onto W.C. Seat

D Transfer Is Complete. Body Stability Is Maintained by Grasping Grab Bar and Seat of Chair

TECHNIQUE FOR SIDE APPROACH TRANSFER



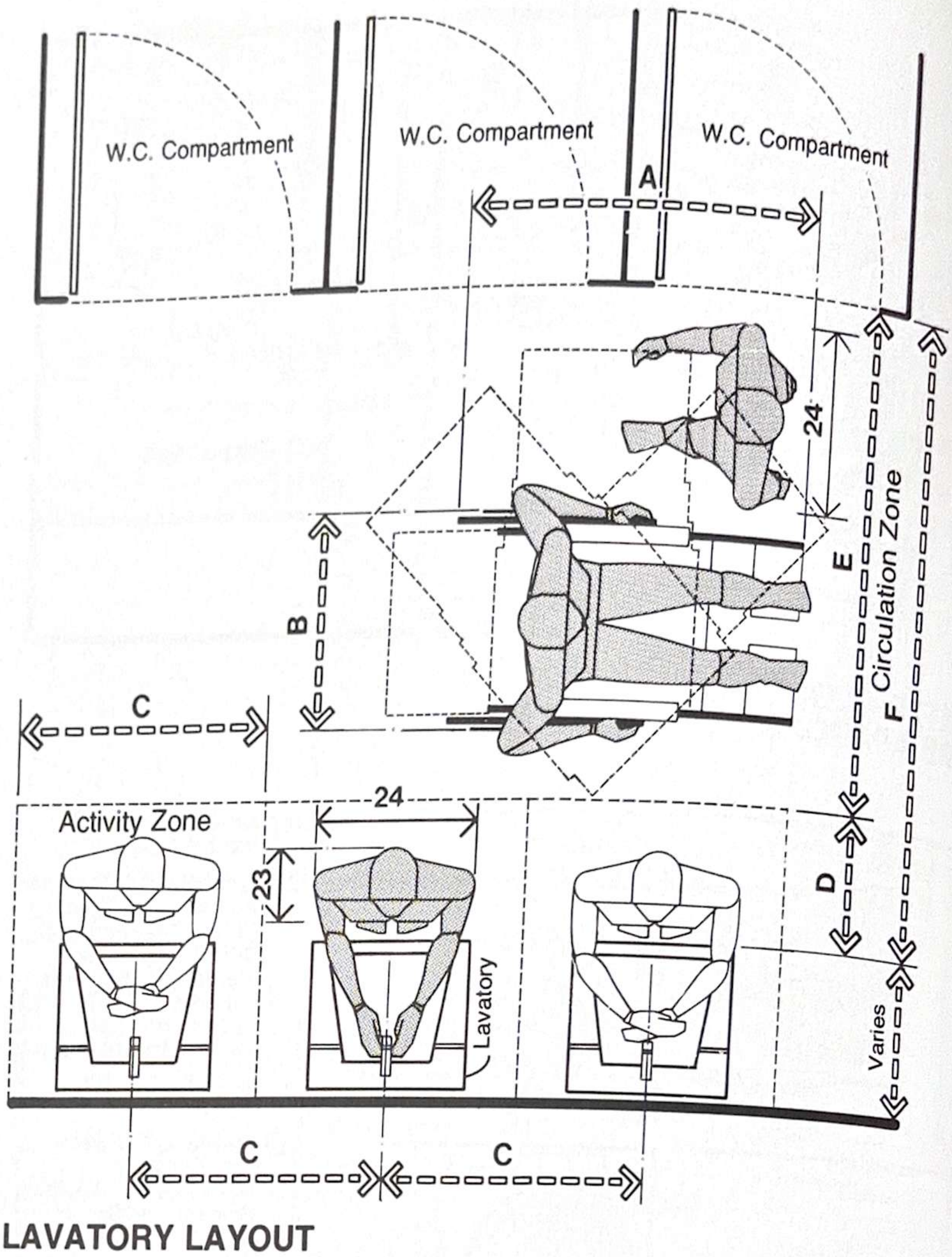
WATER CLOSET

	in	cm
A	72 min.	182.9 min.
B	32	81.3
C	66 min.	167.6 min.
D	18 min.	45.7 min.
E	18	45.7
F	1.5 min.	3.8 min.
G	36	91.4
H	54 min.	137.2 min.
I	58	147.3
J	12	30.5
K	30 max.	76.2 max.
L	10	25.4
M	14–15	35.6–38.1

Printed in China

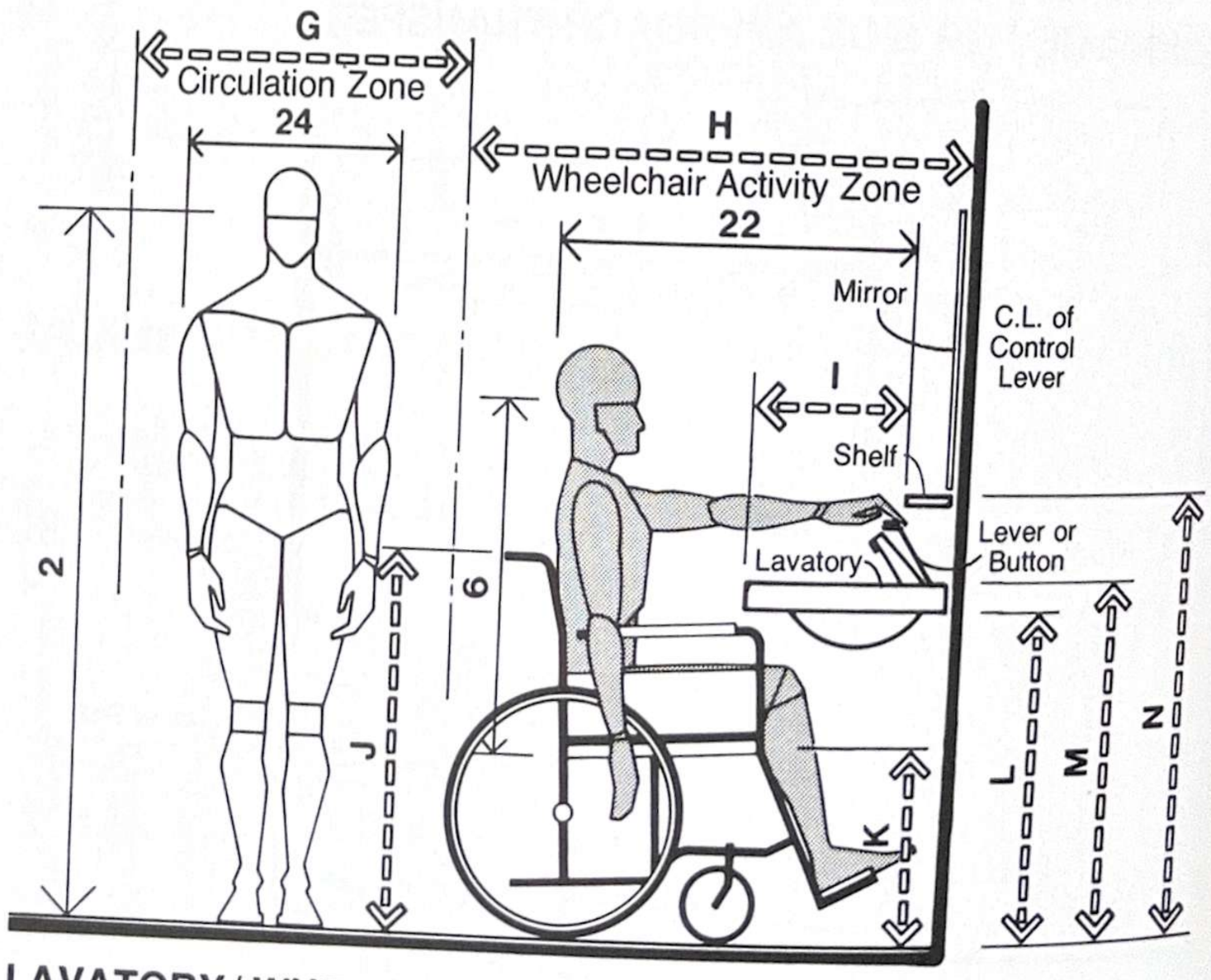
8.3 PUBLIC BATHROOMS

Lavatories, like urinals, are all too often located too close to each other. The result is an installation that may save floor space and may conform to the code in terms of quantity of fixtures, but simply does not permit the user comfortable access. It has been stated elsewhere that the larger-sized person has a maximum clothed body breadth dimension of almost 26 in, or 66 cm, which already exceeds the width of most lavatory models usually specified for public rest rooms. The body movements involved in the washing and grooming process increase the space occupied by the user even more. Unless adequate space is provided, body contact with the adjacent user will occur. A 32-in, or 81.3-cm, spacing as shown should provide for comfortable use of the fixtures. An activity zone of 18 in, or 45.7 cm, in front of the fixtures should be assumed. A circulation zone of 54 in, or 137.2 cm, is the minimum dimension that will allow for both wheelchair and pedestrian traffic. The drawing at the bottom indicates some of the basic clearances and heights required to make the lavatory accessible to the wheelchair user.



LAVATORY LAYOUT

	in	cm
A	42	106.7
B	25	63.5
C	32	81.3
D	18	45.7
E	54	137.2
F	72	182.9
G	30 min.	76.2 min.
H	48	121.9
I	18 max.	45.7 max.
J	36	91.4
K	19	48.3
L	30 min.	76.2 min.
M	34 max.	86.4 max.
N	40 max.	101.6 max.



LAVATORY/ WHEELCHAIR USER

8.4 PUBLIC CONVENIENCE FACILITIES

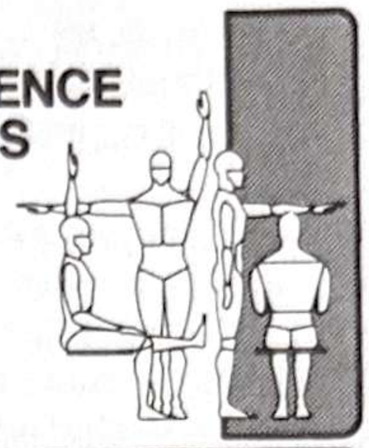


TABLE	TELEPHONE	DRINKING FOUNTAIN	VENDING MACHINE	REFUSE RECEPTACLE
1B,3C	◐			
1C,3B				◐
1F,3G	◐		◐	
1L,2H	●			
1N,2J	◐			
1O,2K	◐			
1P,2L	●			
1V,4D				○
1W,6B	●			

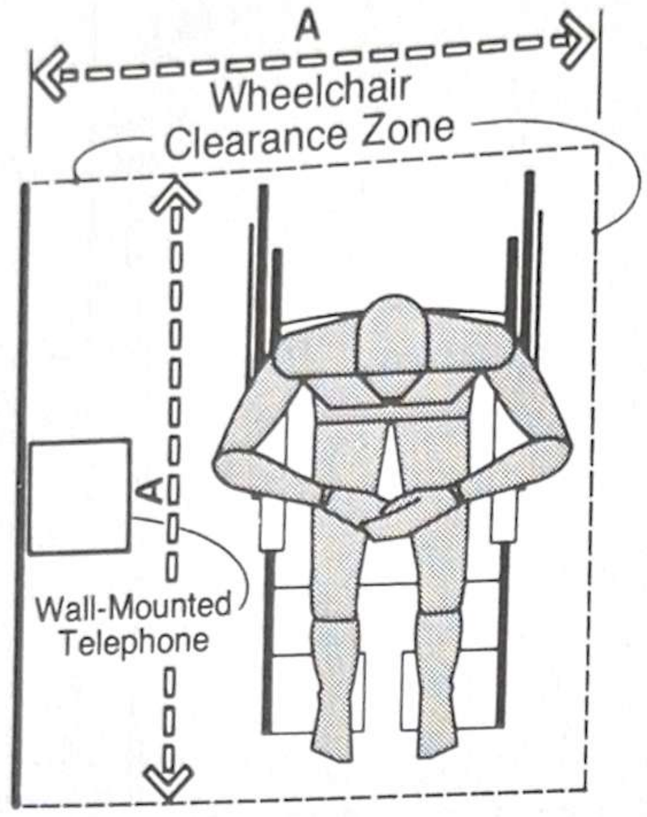
ACTIVITIES	ANTHROPOMETRIC DATA
2	EYE HEIGHT
3	ELBOW HEIGHT
6	EYE HEIGHT SITTING
12	THIGH CLEARANCE
14	POPLITEAL HEIGHT
15	BUTTOCK-POPLITEAL LENGTH
16	BUTTOCK-KNEE LENGTH
22	THUMB TIP REACH
23	MAXIMUM BODY DEPTH

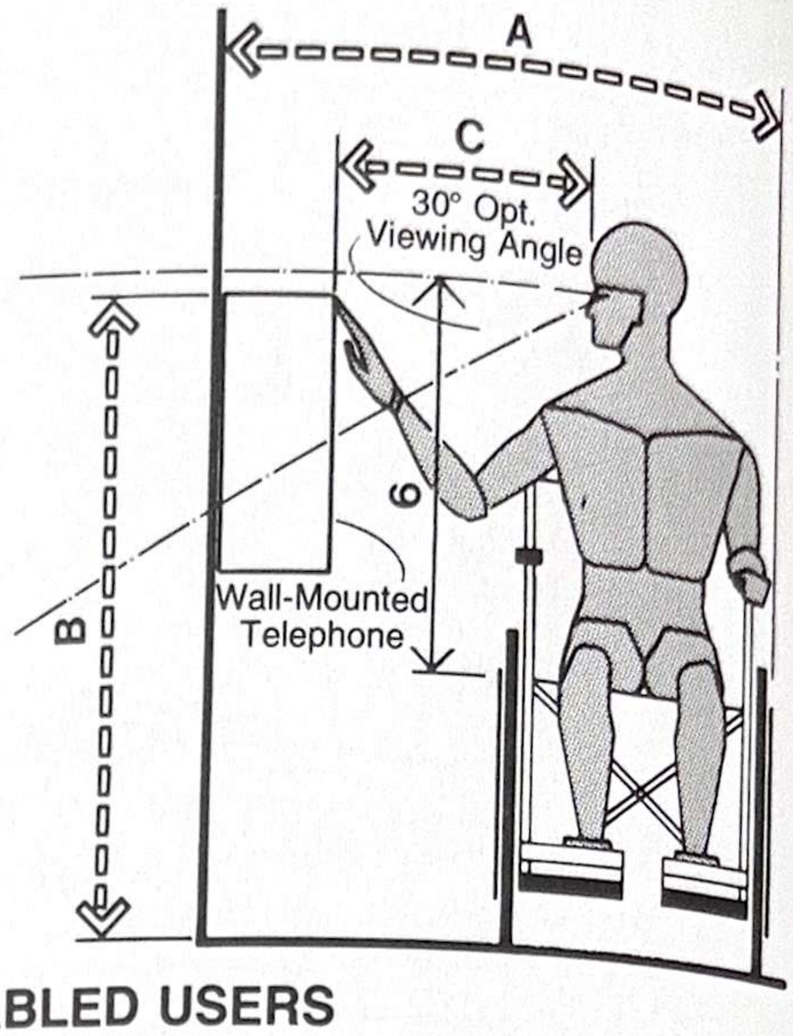
Public convenience facilities must be provided in the design of public spaces. The type and quantity of such facilities will vary depending on the size and nature of the public space involved. They may range from a modest but strategically placed ash urn to a battery of public telephones. It is essential that these facilities be accessible to able-bodied people as well as to semiambulant, elderly, and chair-bound people. The quality of interface between the user and these facilities requires a knowledge of human dimension. A public phone, for example, does a chair-bound user no good if he can't reach the coin slot. The drawings on the following pages illustrate some typical situations showing the human body in relation to a range of some basic public convenience facilities encountered in public spaces. The anthropometric measurements of major concern in the design and placement of these facilities are indicated in the matrix above.

8.4 PUBLIC CONVENIENCE FACILITIES

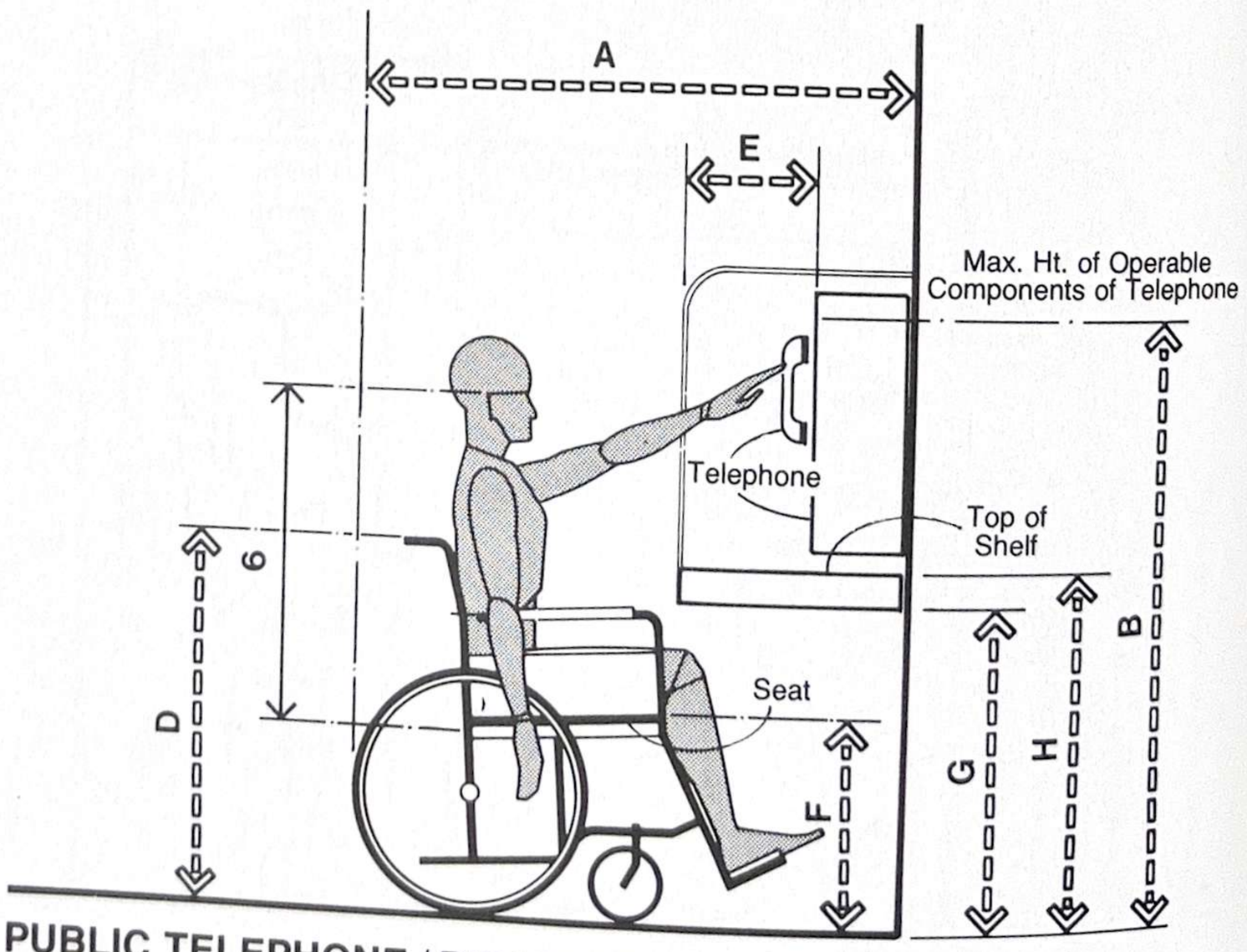
For public telephones to be accessible to wheelchair users, dial, coin slot, and head set should not be more than 48 in, or 121.9 cm, above the floor. It is also desirable that adjustable volume control be provided with the headset to assist those with hearing disabilities. Tactile and visual instructions should be provided for those users with sight disabilities. Wall-mounted units should have adequate space for wheelchair approach parallel to the front face of the equipment. Where shelves are provided below the telephone unit, a clearance of at least 29 in, or 73.7 cm, from the floor to the underside of the lowest part of the shelf should be provided.

If booths are provided for the chair-bound, at least 42 in, or 106.7 cm, of clear floor space should be provided between walls. The telephone unit should be mounted on the side wall and a 32-in, or 81.3-cm, clear door opening should be provided.





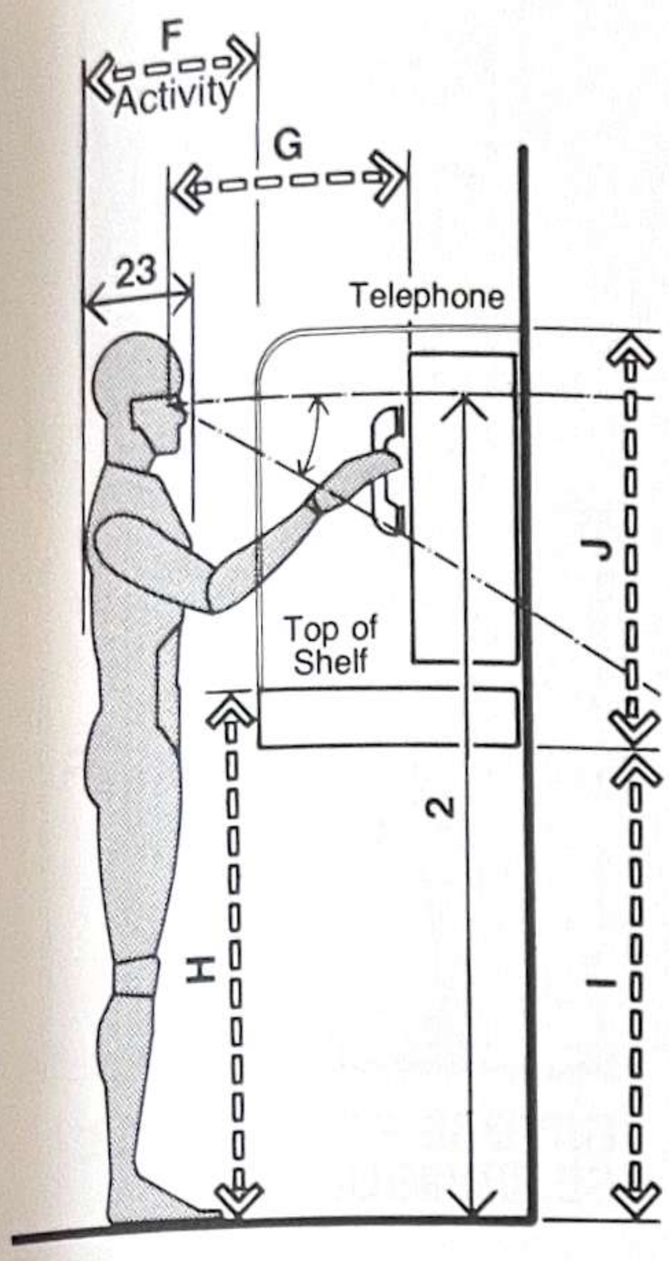
PUBLIC TELEPHONES / DISABLED USERS



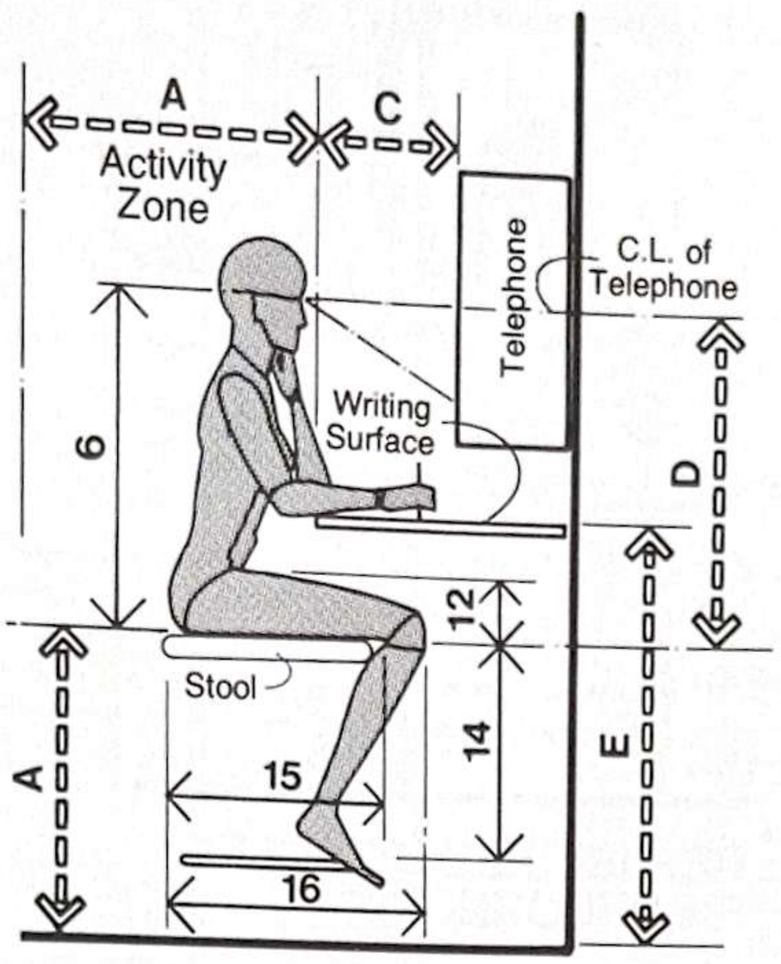
	in	cm
A	48	121.9
B	48 max.	121.9 max.
C	13–20	33.0–50.8
D	36	91.4
E	8–12	20.3–30.5
F	19	48.3
G	29 min.	73.7 min.
H	32 max.	81.3 max.

PUBLIC TELEPHONE / DISABLED USER

8.4 PUBLIC CONVENIENCE FACILITIES



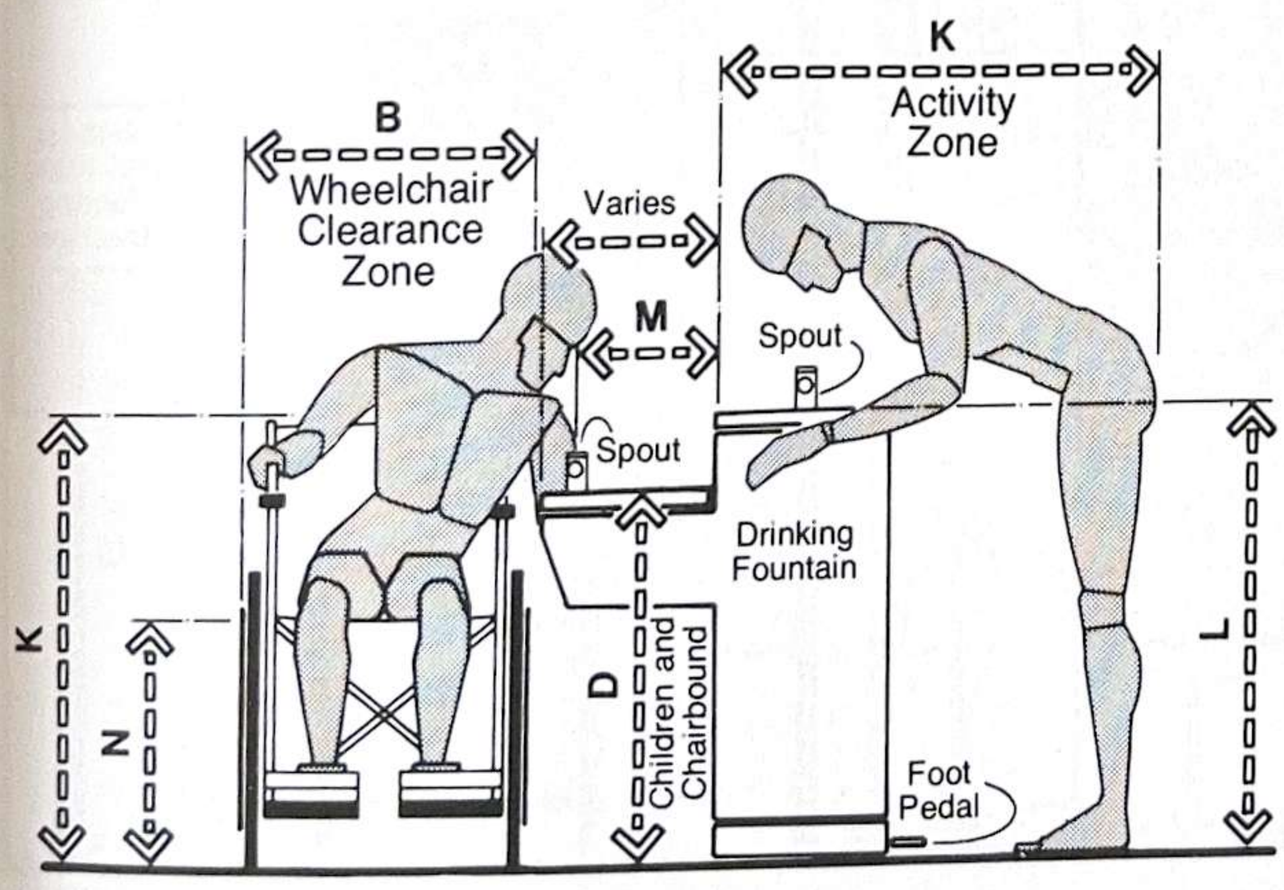
TELEPHONE/
STANDING USER



TELEPHONE/
SEATED USER

The top drawings indicate some of the key dimensions for a wall-mounted public telephone. The installation intended to serve the seated user should comfortably serve a large number of standing users as well.

The drawing at the bottom shows the criticai measurements necessary so that a drinking fountain can be accessible to both handicapped and able-bodied people. A distance of 30 in, or 76.2 cm, from the rim to the floor will make the fountain accessible to both wheelchair users and children. Some codes allow the use of a conventional drinking fountain to serve the wheelchair user if it does not exceed 36 in, or 91.4 cm, in height. The authors suggest that the 30-in height be used and, if necessary, a maximum height of 34 in, or 86.4 cm, not be exceeded. It is recommended also that hand-operated controls or combined hand-and-foot controls be used.



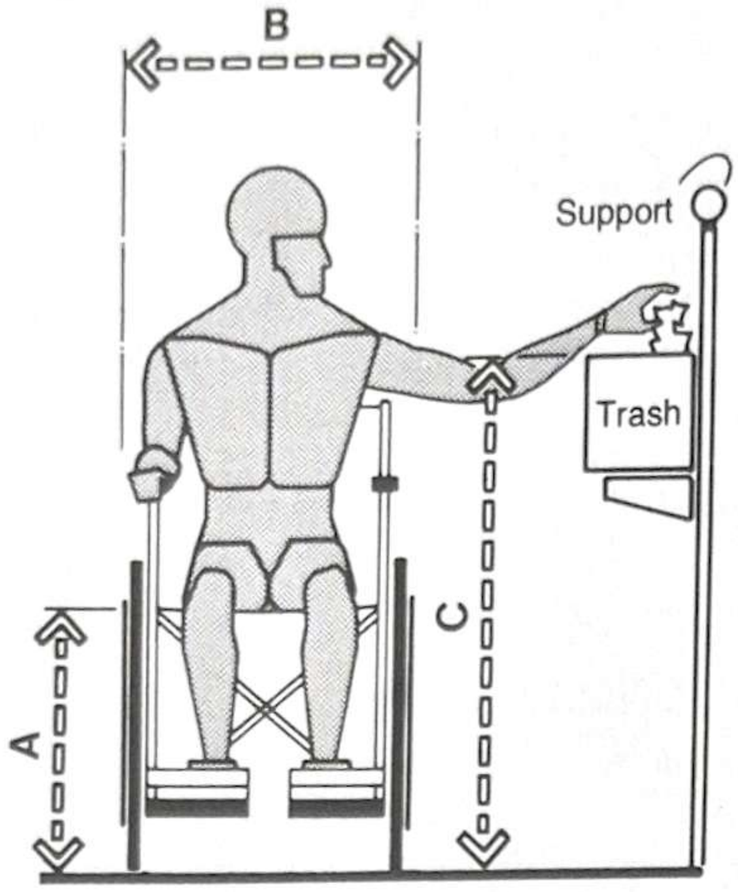
DRINKING FOUNTAIN HEIGHTS

	in	cm
A	24	61.0
B	25	63.5
C	12	30.5
D	30	76.2
E	34	86.4
F	18	45.7
G	13–20	33.0–50.8
H	43	109.2
I	37	94.0
J	32.5	82.6
K	36	91.4
L	36 max.	91.4 max.
M	8 min.	20.3 min.
N	19	48.3

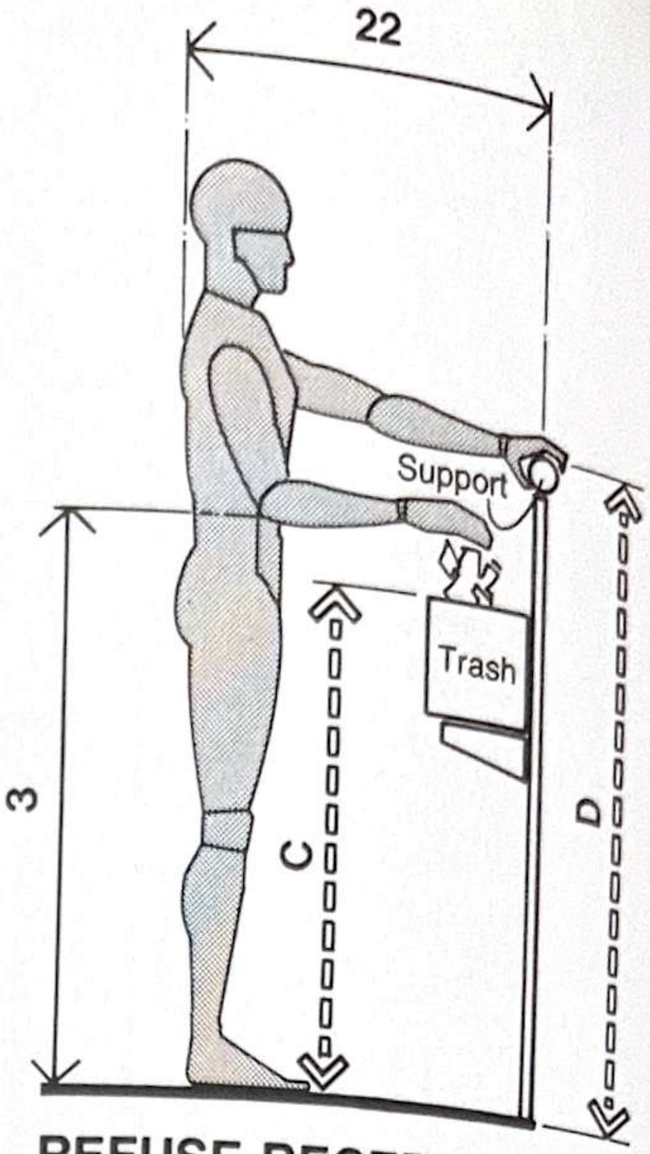
8.4 PUBLIC CONVENIENCE FACILITIES

The top drawings indicate recommended heights for refuse receptacles to serve chairbound and semiambulant users. Provisions for a support can be extremely helpful.

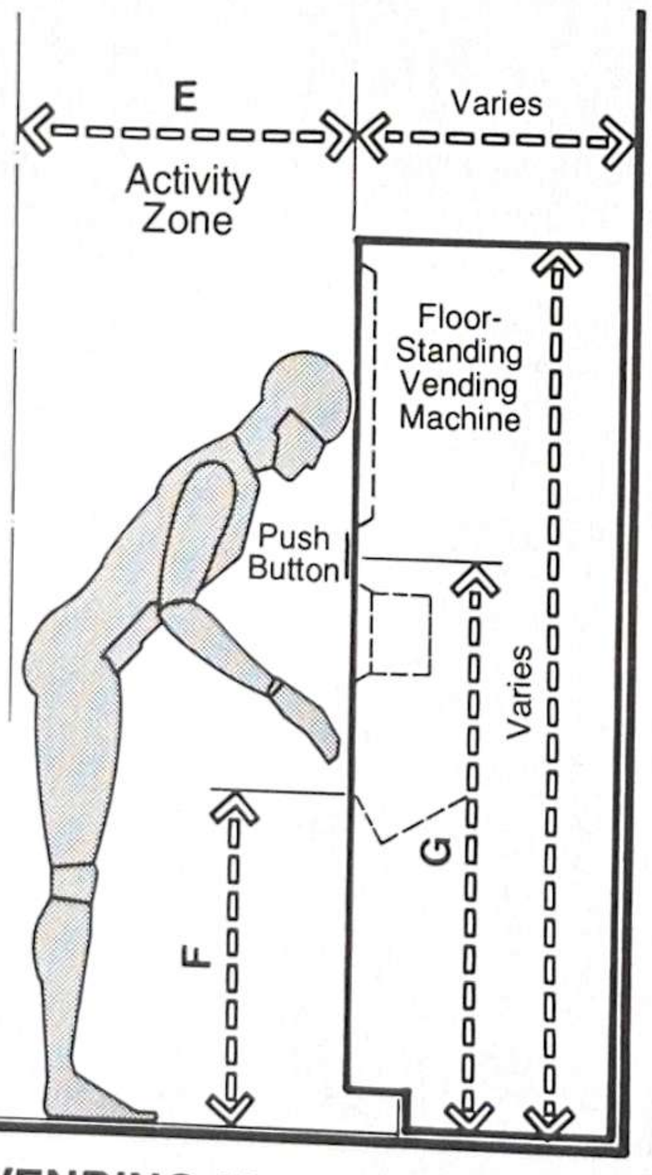
The drawings at the bottom show a floor-type and wall-hung or shelf-type vending machine installation. Proper location of operating controls and coin slots is essential if the machines are to serve handicapped as well as able-bodied people. To be accessible to the chairbound user, the controls should be no less than 24 in, or 61.0 cm, nor more than 48 in, or 121.9 cm, above the floor. An activity zone of 42 in, or 106.7 cm, should be assumed in front of the machine for a person in a wheelchair. Where purely mechanical pull devices are used, they should require a minimal amount of force for operation.

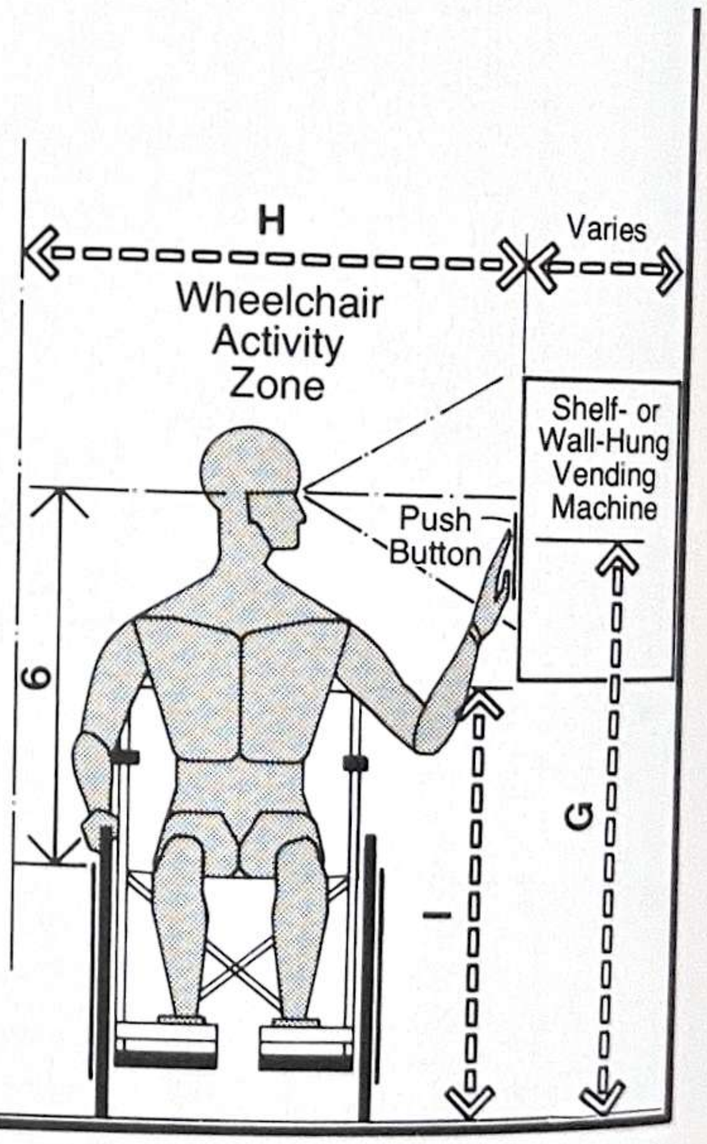


REFUSE RECEPTACLE/ CHAIRBOUND



REFUSE RECEPTACLE/ SEMIAMBULANT

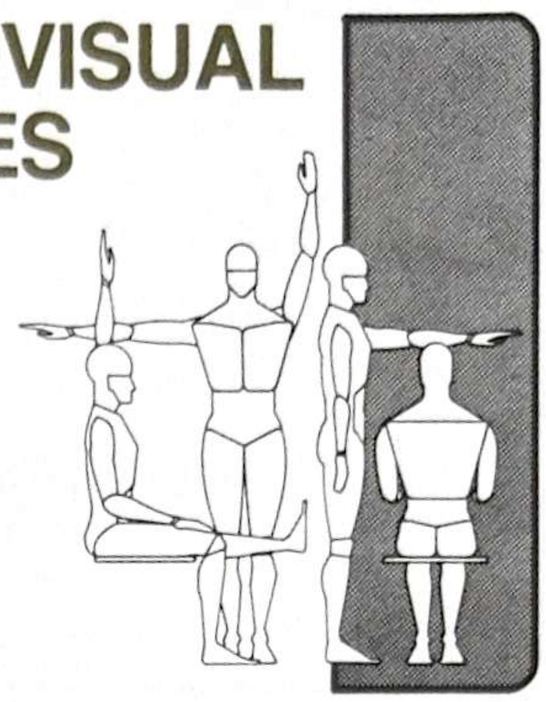




VENDING MACHINES

	in	cm
A	19	48.3
B	25	63.5
C	40	101.6
D	48–54	121.9–137.2
E	30	76.2
F	24 min.	61.0 min.
G	48 max.	121.9 max.
H	48	121.9
I	36 max.	91.4 max.

9 AUDIOVISUAL SPACES



SPACE

TABLE	9.1 BASICS	9.2 WORKSTATION DISPLAY	9.3 GROUP VIEWING DISPLAYS	ANTHROPOMETRIC DATA
1A,2B			◪	1 STATURE
1B,3C		◪	◪	2 EYE HEIGHT
1C,3B			◪	3 ELBOW HEIGHT
				4 SITTING HEIGHT ERECT
1E,2D			◪	5 SITTING HEIGHT NORMAL
1F,3G		◪	◪	6 EYE HEIGHT SITTING
				7 MIDSHOULDER HEIGHT SITTING
				8 SHOULDER BREADTH
				9 ELBOW-TO-ELBOW BREADTH
				10 HIP BREADTH
				11 ELBOW REST HEIGHT
1L,2H		●		12 THIGH CLEARANCE
1M,2I		●		13 KNEE HEIGHT
1N,2J		◪	◪	14 POPLITEAL HEIGHT
1O,2K		◪	◪	15 BUTTOCK-POPLITEAL LENGTH
1P,2L		●	●	16 BUTTOCK-KNEE LENGTH
1Q,3F		●	●	17 BUTTOCK-TOE LENGTH
				18 BUTTOCK-HEEL LENGTH
				19 VERTICAL REACH HEIGHT SITTING
				20 VERTICAL GRIP REACH
				21 SIDE ARM REACH
1V,4D		○		22 THUMB TIP REACH
1W,6B			●	23 MAXIMUM BODY DEPTH
1X,6A			●	24 MAXIMUM BODY BREADTH
9	●			25 ROTATION
9	●			26 FLEXION
9	●			27 HYPEREXTENSION
9			●	28 ECTOCANTHUS TO TOP OF HEAD

In recent years, the information explosion has given rise to a wide variety of audiovisual systems required to transmit that information. Applications can be found in almost every sector of the business and educational community. Trading rooms in brokerage houses, screening rooms in advertising agencies, conference rooms in corporate offices, libraries, auditoriums, and lecture halls in educational institutions are only a few of the many interior spaces for which visual communications systems must be planned. The systems range in complexity from a simple television readout to serve a single viewer at a workstation to multiscreen audiovisual presentations in an auditorium seating several hundred people.

Projections for the future include the use of closed circuit television for international conferences via satellite/sight transmission. Conferences between personnel of branch offices of large business corporations via closed circuit television, already a reality, may become routine. The use of audiovisual communications systems in the educational field is increasing rapidly, and some speculate that students soon will receive a greater portion of their education through film, slides, television, and computers than through live instruction. In terms of residential applications, the advent of CB radios, home computers, video tape cassettes, sophisticated stereophonic sound systems, home sound movies all clearly indicate that sophisticated audiovisual communications systems will become as much a part of tomorrow's home as was the radio in the thirties and forties and the TV in the fifties, sixties, and seventies. The design of audiovisual spaces requires some knowledge of acoustics, audition, and human vision. It is with respect to vision, however, that anthropometrics are particularly significant. Accordingly, the human eye and visual field serve as the basis for the drawings and data on the following pages. The eye height of short people compared with that of tall people in standing and seated positions, the difference in eye heights between males and females, the extent of a person's visual field, comfortable viewing zones, and the degree to which head movement and eye rotation can increase viewing capability are all essential factors in ensuring the proper interface between viewer and visual communication system.

9.1 BASICS

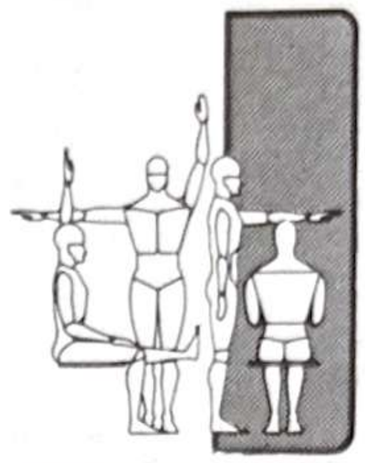


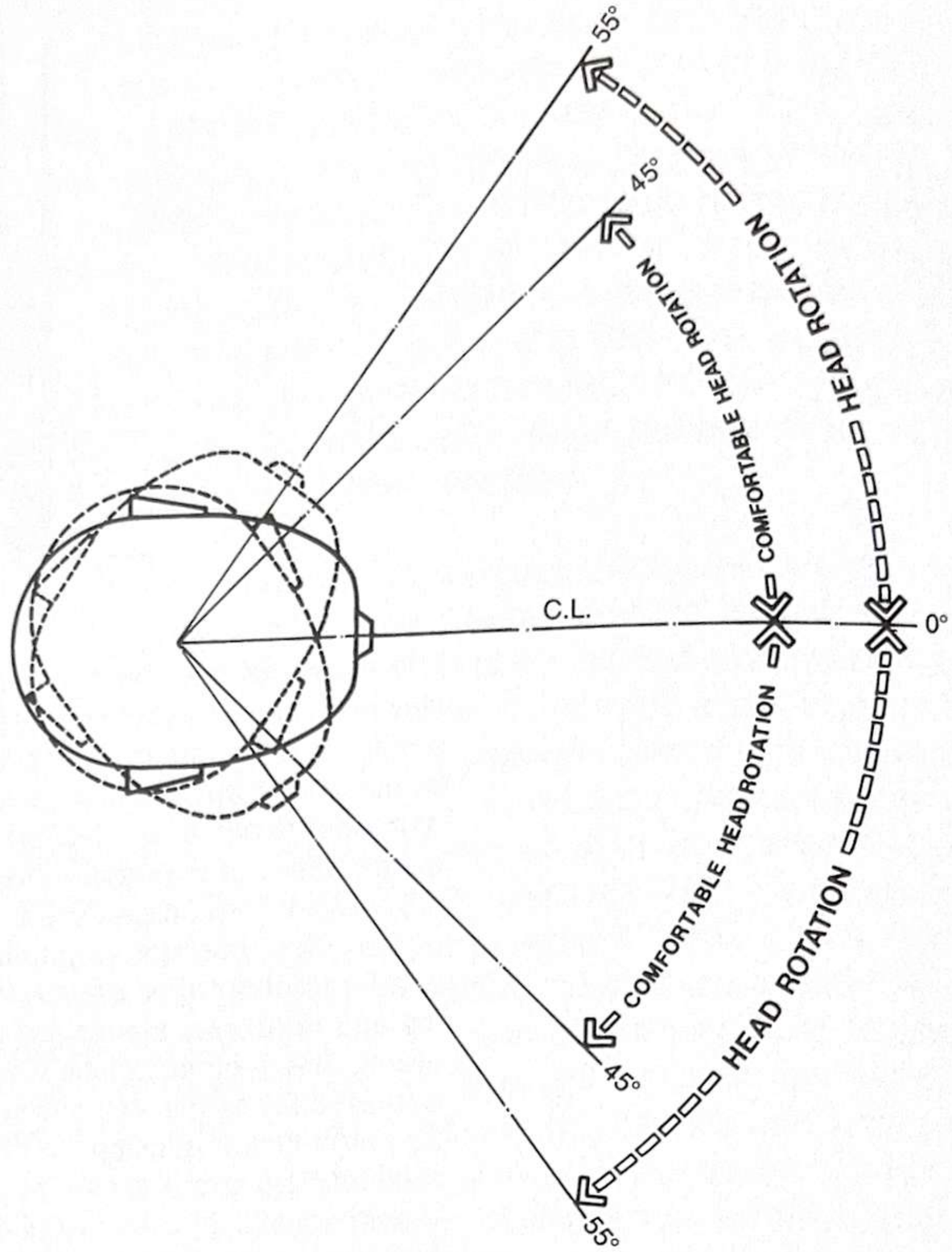
TABLE	BASICS	ACTIVITIES	ANTHROPOMETRIC DATA
9	●	25	ROTATION
9	●	26	FLEXION
9	●	27	HYPEREXTENSION

The quality of the interface between any visual communication system and the viewer is, to a very large degree, a function of the extent to which the design of that system and the interior space in which it is housed responds to certain fundamental human capabilities and constraints. The more important factors for the architect or interior designer to consider involve the biomechanics of the human body and the geometry of the visual field. A third factor, the eye heights of seated and standing viewers, will also be discussed in the following section. In regard to biomechanics, the area of particular concern centers on the limits of the range of head movement. The degree to which the viewer may rotate the head in the vertical and horizontal planes will quite obviously widen or restrict his or her field of vision. The geometry of the visual field is equally significant since this aspect of the eye establishes the viewer's cones of vision and related viewing angles. It should be noted that in addition to head movement, the eyes themselves are capable of rotation. The range of eye movement up or down or from side to side adds to the viewer's ability to scan visual displays. The drawings on the following pages deal with the basics: the range of head movement in the horizontal and vertical planes and the visual field in the horizontal and vertical planes.

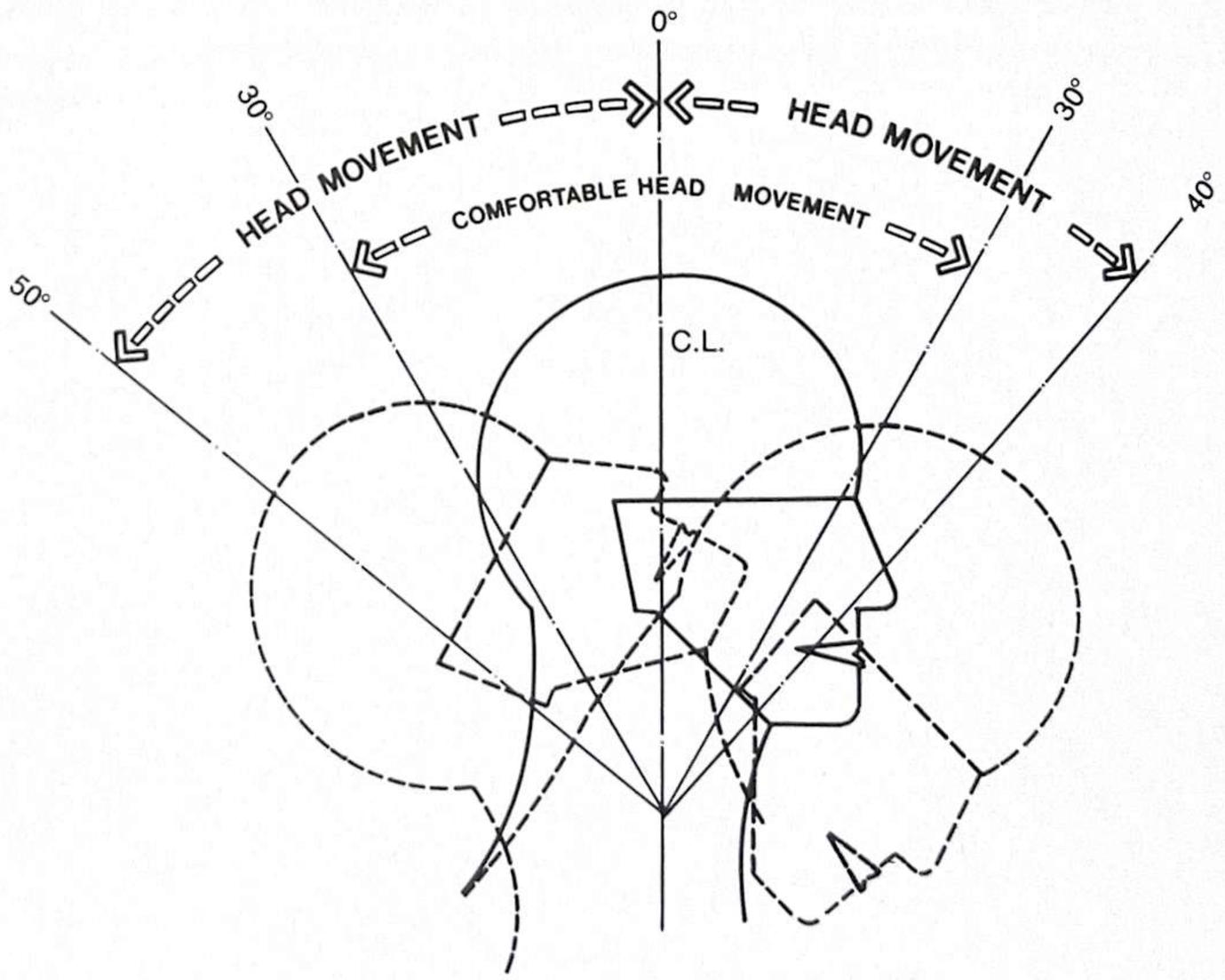
9.1 BASICS

Joint motions and positions are usually recorded in three basic planes—sagittal, frontal or coronal, and transverse—or in planes parallel to them. The sagittal plane is a vertical plane taken through the center of the body and perpendicular to body breadth. The frontal or coronal plane is also a vertical plane and is assumed to be taken through the body and perpendicular to the sagittal plane. The transverse plane is a horizontal plane perpendicular to the other two planes. For purposes of biokinematic research, these three planes are viewed as an orthogonal axis system centered on the pelvis.

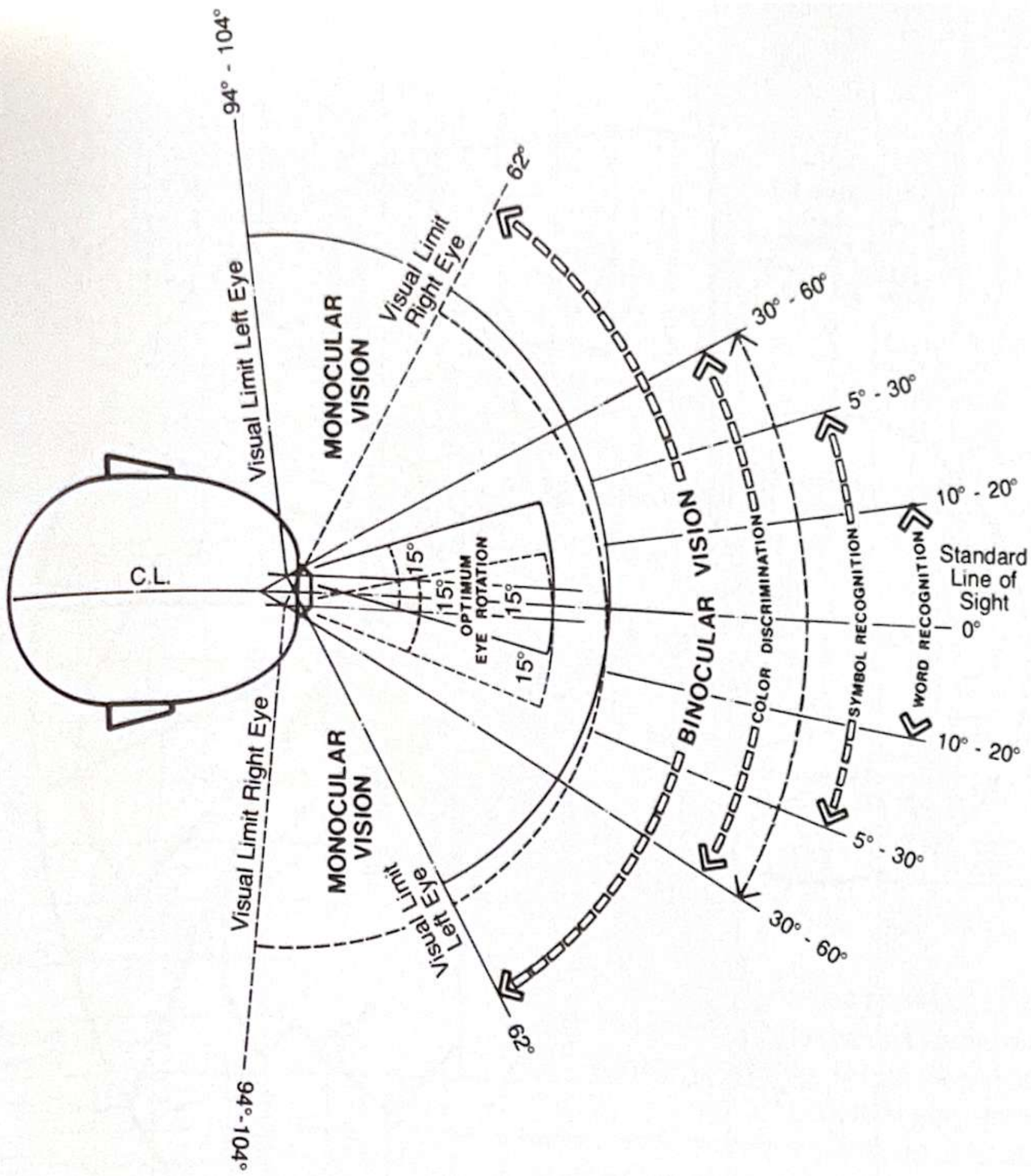
The top drawing illustrates the range of head movement in the transverse or horizontal plane. Anthropometrically, the motion is referred to as "neck rotation" and a range of 45° to the left or right can be achieved without strain or discomfort by most people. A simple trial rotation by the reader will demonstrate the tremendous increase in the area that can be scanned from a single fixed location. The lower drawing illustrates the range of head movement in the vertical or sagittal plane. A range from 0° to 30° in either direction is possible without discomfort. Anthropometrically, the movement is termed "neck flexion." If measured downward, it is described as "ventral," and if measured toward the back or upward, it is described as "dorsal." International Standard Orthopaedic Measurements (ISOM), however, refer to the downward motion as "flexion" and the upward motion as "extension." Again, a simple experiment by the reader illustrates the tremendous increase in the field that can be scanned as a result of head movement, even if that movement is only a few degrees in magnitude.



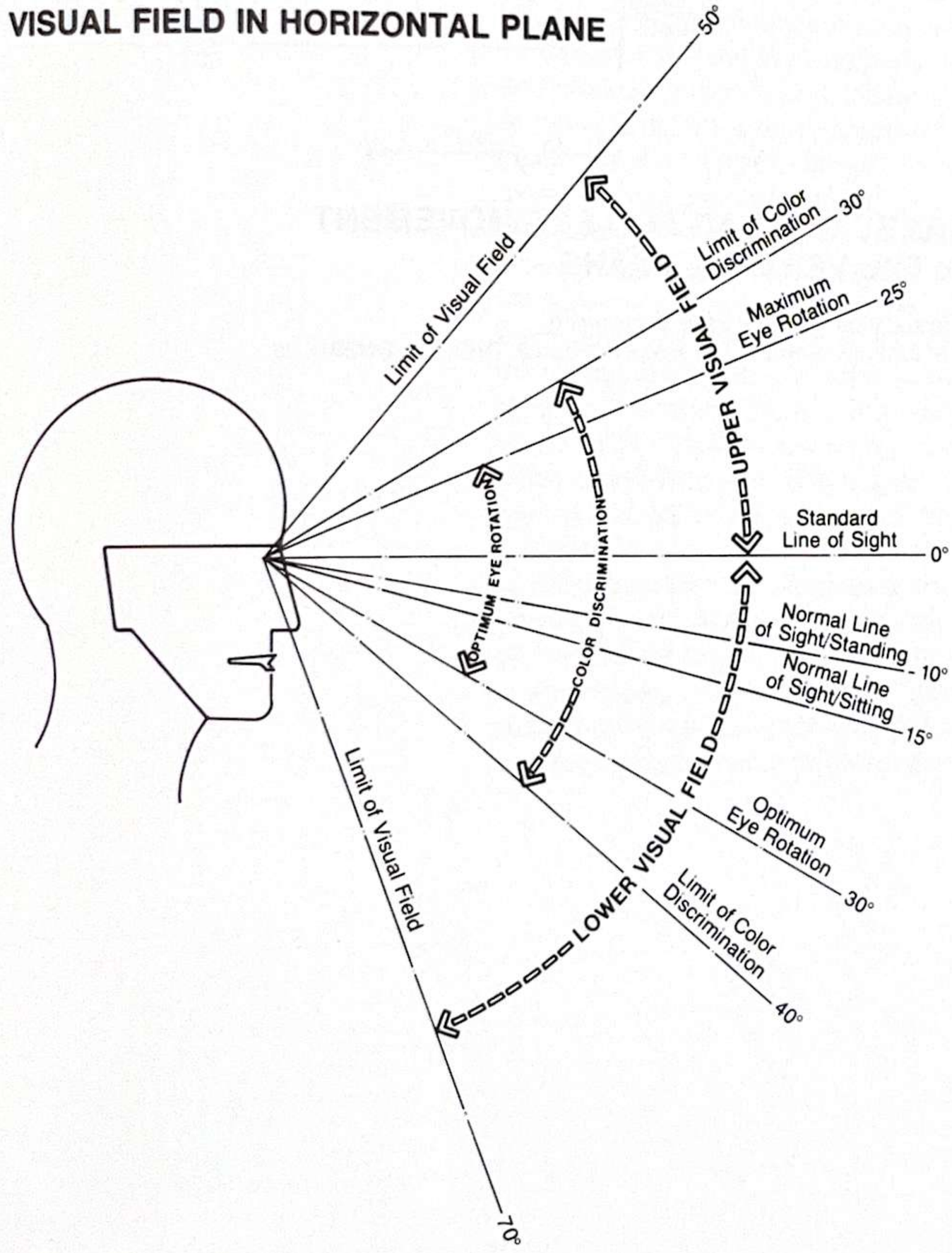
HEAD MOVEMENT IN HORIZONTAL PLANE



HEAD MOVEMENT IN VERTICAL PLANE



VISUAL FIELD IN HORIZONTAL PLANE



VISUAL FIELD IN VERTICAL PLANE

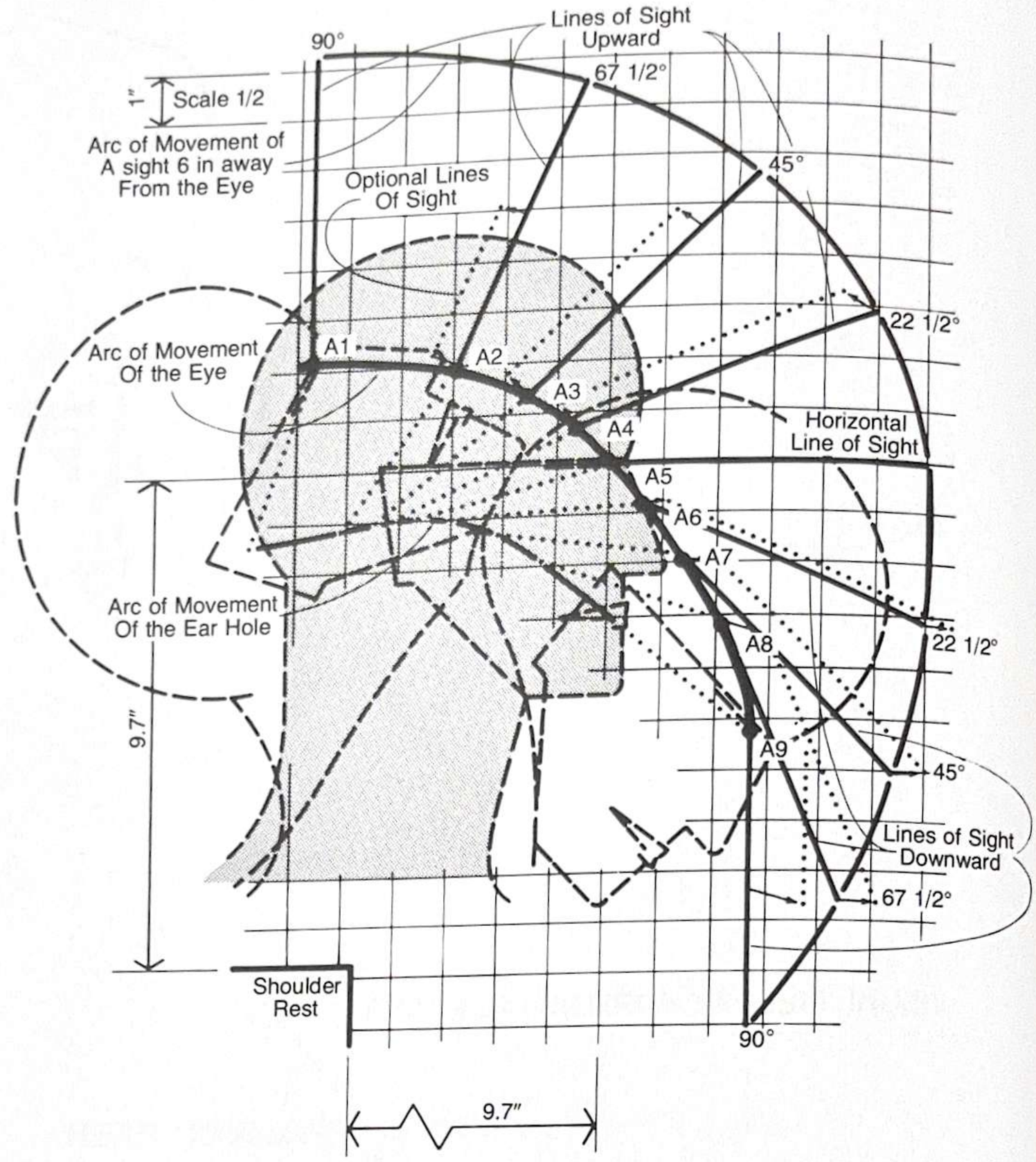
9.1 BASICS

The visual field is that part of space, measured in angular magnitude, that can be seen when the head and the eye are absolutely still. The visual field of the individual eye is termed "monocular vision." Within this field sharp images are not transmitted to the brain, causing objects to appear unclear and diffused. When an object, however, is observed by both eyes simultaneously, the visual field of each individual eye overlaps, creating a central field of greater magnitude than that possible by each eye separately. This central field of vision is termed "binocular field" and, as indicated in the top drawing, is about 60° in each direction. Within this field very sharp images are transmitted to the brain, depth perception occurs, and color discrimination is possible. Within this central field, recognition of words and symbols also occurs: 10° to 20° of the line of sight for the former and 5° to 30° of the line of sight for the latter. Beyond these respective limits, both words and symbols tend to disappear. The area of the sharpest focus is actually about 1° either side of the sight line. Depending on the particular color, color begins to disappear between 30° and 60° of the line of sight.

As shown in the drawing at the bottom of the page, the standard line of sight is assumed to be horizontal and at 0°. A person's natural or normal line of sight, however, is actually below the horizontal and varies slightly depending upon each individual and whether he is standing or sitting. If standing, the normal line of sight is about 10° below the horizontal and if sitting about 15°. In a very relaxed position, both standing and sitting sight lines may drift to an even greater angle below the horizontal: about 30° and 38° respectively. The magnitude of the optimum viewing zone for display materials is about 30° below the standard line of sight.

9.1 BASICS

The preceding drawings serve to individually illustrate the range of head movement in the horizontal and vertical planes and the field of vision in the horizontal and vertical planes. The drawing here combines both the head and eye movements in the vertical plane involved in sighting at various angles above and below the horizontal plane. Although the diagram itself may be of little, if any, practical use to the interior designer or the architect, it serves to stress the extent to which the area that can be scanned is affected by the range of head and eye movement.



RANGE OF HEAD AND EYE MOVEMENT IN THE VERTICAL PLANE

Adapted from *Human Factors Engineering*, U.S. Air Force Systems Command Handbook, DH1-3, P. DN2B11, 19.

9.2 WORKSTATION DISPLAYS

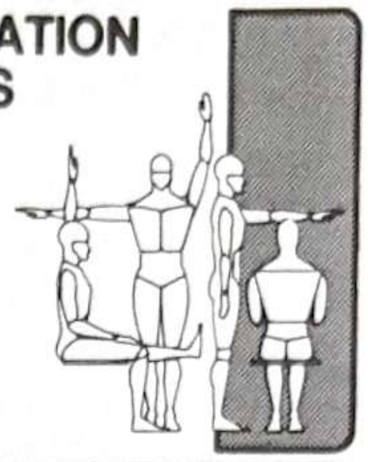


TABLE	SEATED VIEWING	STANDING VIEWING	ACTIVITIES	ANTHROPOMETRIC DATA
1B,3C	◑		2	EYE HEIGHT
1F,3G	◑	◑	6	EYE HEIGHT SITTING
1L,2H		●	12	THIGH CLEARANCE
1M,2I		●	13	KNEE HEIGHT
1N,2J		◑	14	POPLITEAL HEIGHT
1O,2K		◑	15	BUTTOCK-POPLITEAL LENGTH
1P,2L		●	16	BUTTOCK-KNEE LENGTH
1Q,3F		●	17	BUTTOCK-TOE LENGTH
1V,4D		○	22	THUMB TIP REACH

The interior designer or architect is frequently faced with the design of interior spaces and/or cabinet work that must incorporate a visual communication system of one type or another for an individual viewer. The system will inevitably include display material to be viewed from a sitting or a standing position. The viewing time may vary from a few moments to situations where the viewing task may well be a full-time activity. The display material may be in the form of a television readout, a film clip, or a transparency or x-ray negative to be viewed on a backlighted surface. To design the installation properly, the designer must be responsive to both the anthropometric and visual considerations involved. Eye height, for example, sitting or standing is clearly an anthropometric consideration, yet when applied to a visual communication system design, it becomes indistinguishable from what might be more appropriately categorized as an exclusively visual factor. It is the eye height measurement and the cone of vision springing from it that will help determine proper display location. Consideration must also be given to the problem of a very tall viewer and a very short viewer. Can the location of the display accommodate both users? If the display is to be located over a workcounter or desk surface, will the design accommodate the viewer with the shorter reach? If the design accommodates the reach requirements, will it also accommodate the human factor of the visual field and will the display be legible to the viewer? The drawings and data that follow deal exclusively with single-viewer, short-range displays and contain information that will be helpful in resolving some of the design problems posed. Note, however, that the information presented is not intended as a design solution, but as guidelines that can serve as a reasonable basis for preliminary design studies. When one considers the great variety and types of visual displays possible and the extent to which the visual field can be increased by a simple movement of the head or eye rotation, the data can be placed in a proper perspective. Moreover, it is customary in the design of workstations of this type to have a full-scale mockup of the unit for testing prior to production of the final unit.

9.2 WORKSTATION DISPLAYS

The need to include a visual display component as part of an individual workstation is not uncommon. In most cases the display takes the form of some kind of computer readout arrangement. Whatever the nature of the display, the distance between it and the eye and the height and angle of the display is an important consideration. In certain cases displays must be observed from a standing position, in others from a seated position. The workstation must also accommodate people having a wide range of body sizes. The drawings on this and the next page will explore some of the basic visual and anthropometric factors involved.

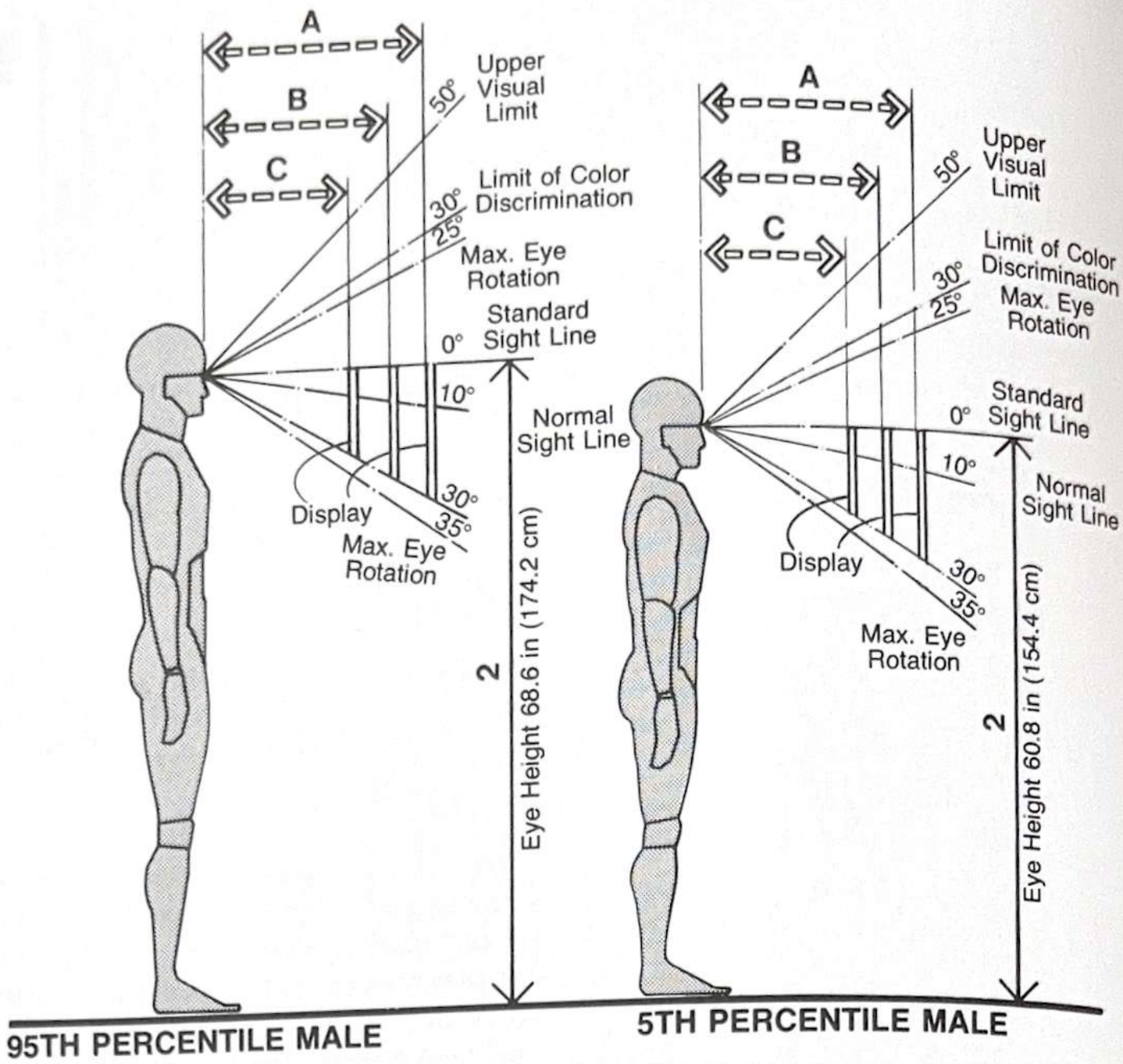
Distance of Display from the Eye

Through the process of accommodation, the mechanism of the human eye will automatically focus the eye on the display at the required distance. Most sources place the minimum distance from viewer to display between 13 and 16 in, or 33 and 40.6 cm; the optimum distance between 18 and 22 in, or 45.7 and 55.9 cm; and the maximum distance between 28 and 29 in, or 71.7 and 73.7 cm.

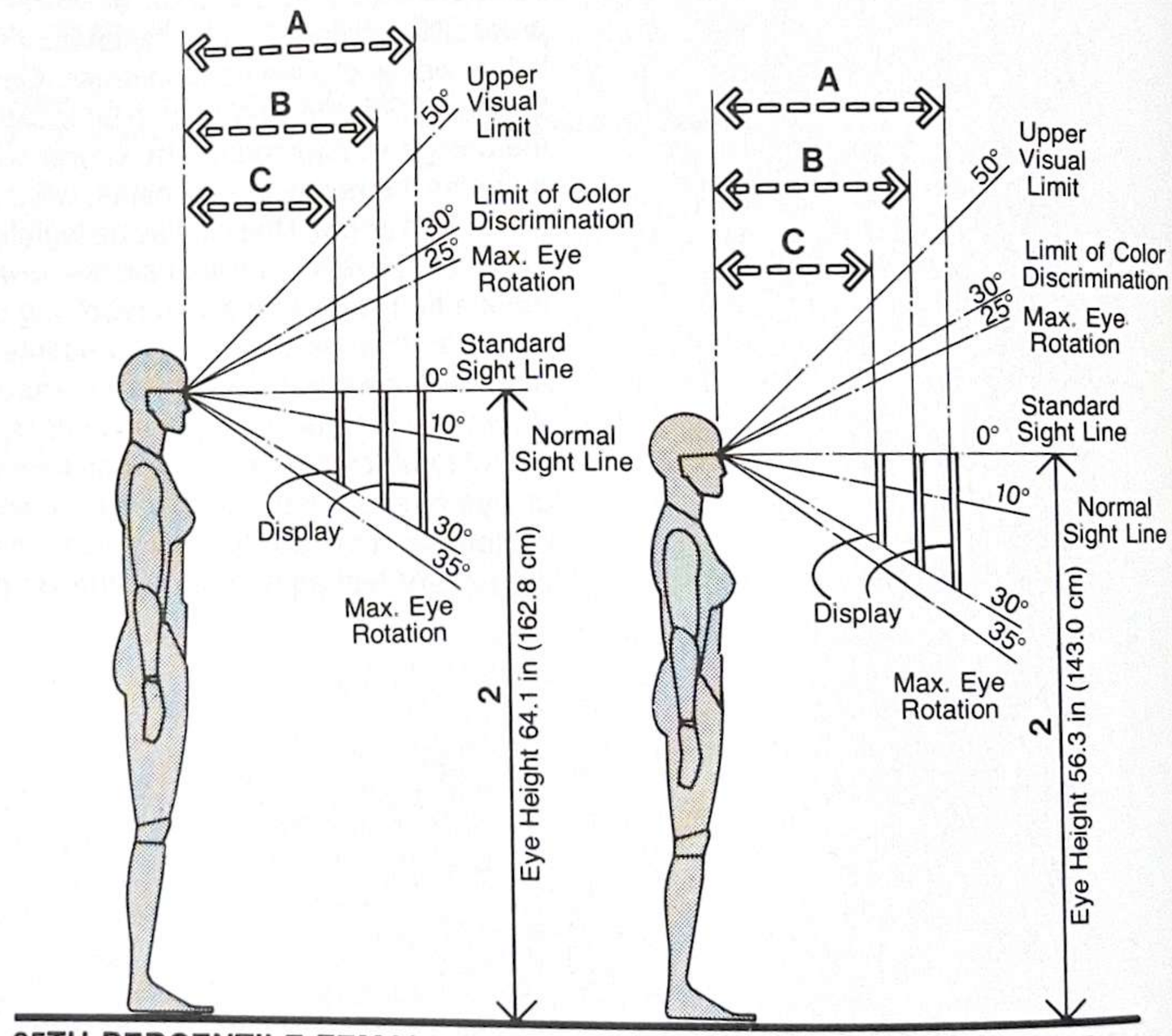
It should be noted, however, that the ranges cited are approximations and vary with the size of the display material and lighting. Moreover, the nearest point to which the eye can focus moves further away from the eye with age. At age 16, for example, it is less than 4 in, or 10.2 cm, away, while at age 40 it is over twice that distance away. By comparison, however, the furthest point to which the eye can focus shows relatively little change over the years. Accordingly, the maximum range of 28 to 29 in, or 71.7 to 73.7 cm, is limited more by the size of the characters and the reach limitations related to the workstation counter or controls. The usual reading distance for printed material is about 18 in, or 45.8 cm.

Viewing Angle

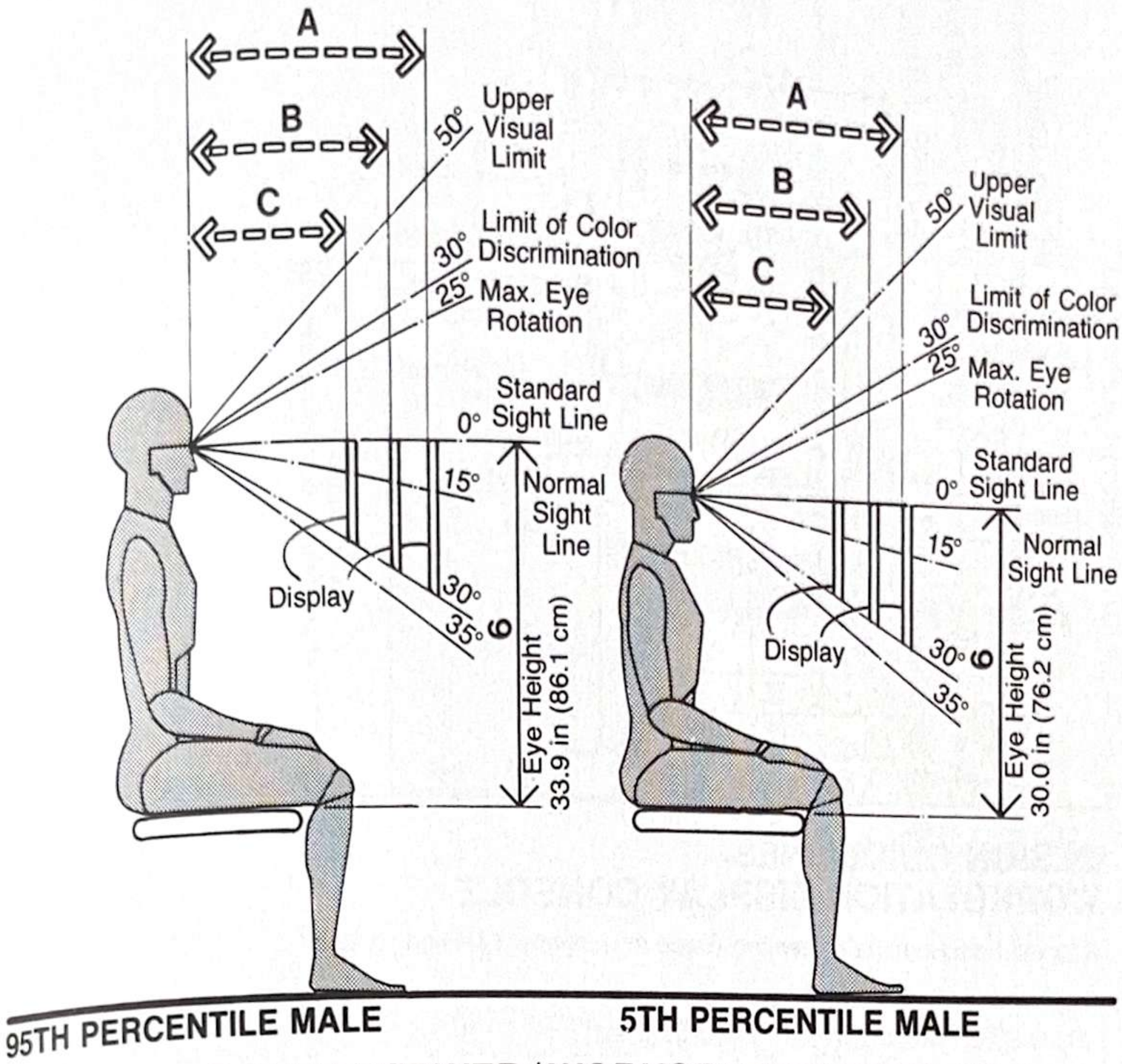
As a general rule for optimum viewing, a sight line from the bottom of the display to the eye of the viewer should form an angle of not more than 30° with the standard horizontal line of sight. In cases where a seated ob-



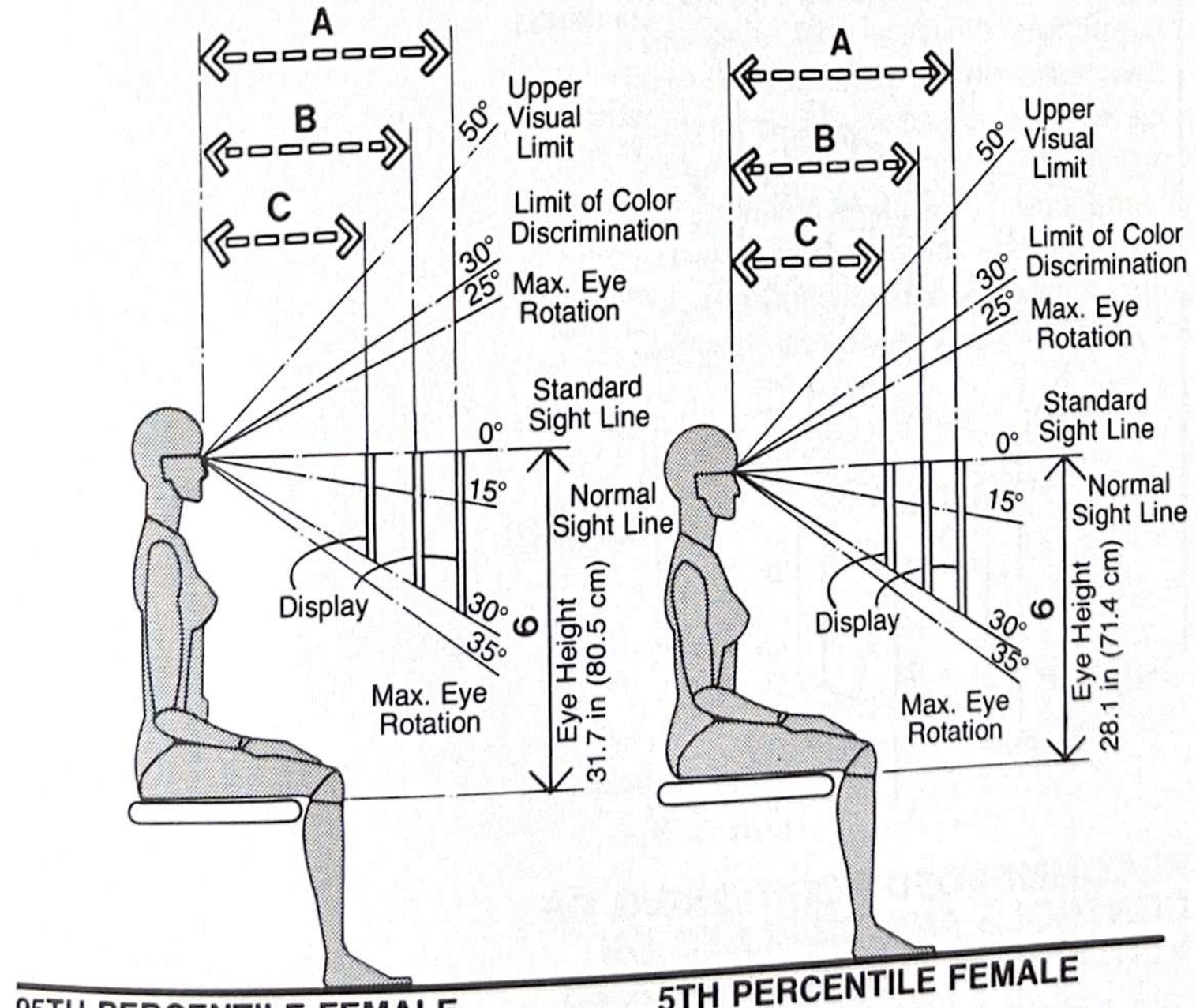
THE STANDING MALE VIEWER / WORKSTATION DISPLAY



THE STANDING FEMALE VIEWER/ WORKSTATION DISPLAY



THE SEATED MALE VIEWER/WORKSTATION DISPLAY



THE SEATED FEMALE VIEWER/WORKSTATION DISPLAY

server is to function at the workstation for an extended period of time, he would, after a while, assume a more relaxed position, causing his head to rotate downward a few more degrees. The 30° could therefore be increased to 33°.

Height of Display

Ideally, the height of the top of the display should relate to the eye height of the viewer. The great variability in eye height measurements and in certain cases the size of the specific display may make this difficult. One solution to make the display within reach and within the visual field of the smaller viewer is to increase his eye height by means of a raised platform. Safety precautions, such as a railing, should be provided to prevent accidents. The platform should be movable so that it can be relocated at such times that the workspace is to be used by a taller viewer. Another solution, although more costly, is to develop an adjustable arrangement, whereby the display panel may be raised or lowered to suit individual eye height. Where a seated viewer is involved, the problem is less difficult. The variation in the eye heights of the tall and short seated viewer above the seat surface is much less than that of the eye heights above the floor of tall and short standing viewers. The difference in eye heights of the latter is about 12 in, or 30.5 cm, while the difference between eye heights of the former, as indicated by the drawings, is less than 6 in, or 15.2 cm. Accordingly, the problem of making the display within reach of the visual field of the smaller seated user can be solved quite easily by the use of a chair with an adjustable seat height.

Display Angle

Where possible, the angle of display should place the viewing surface perpendicular to the normal line of sight.

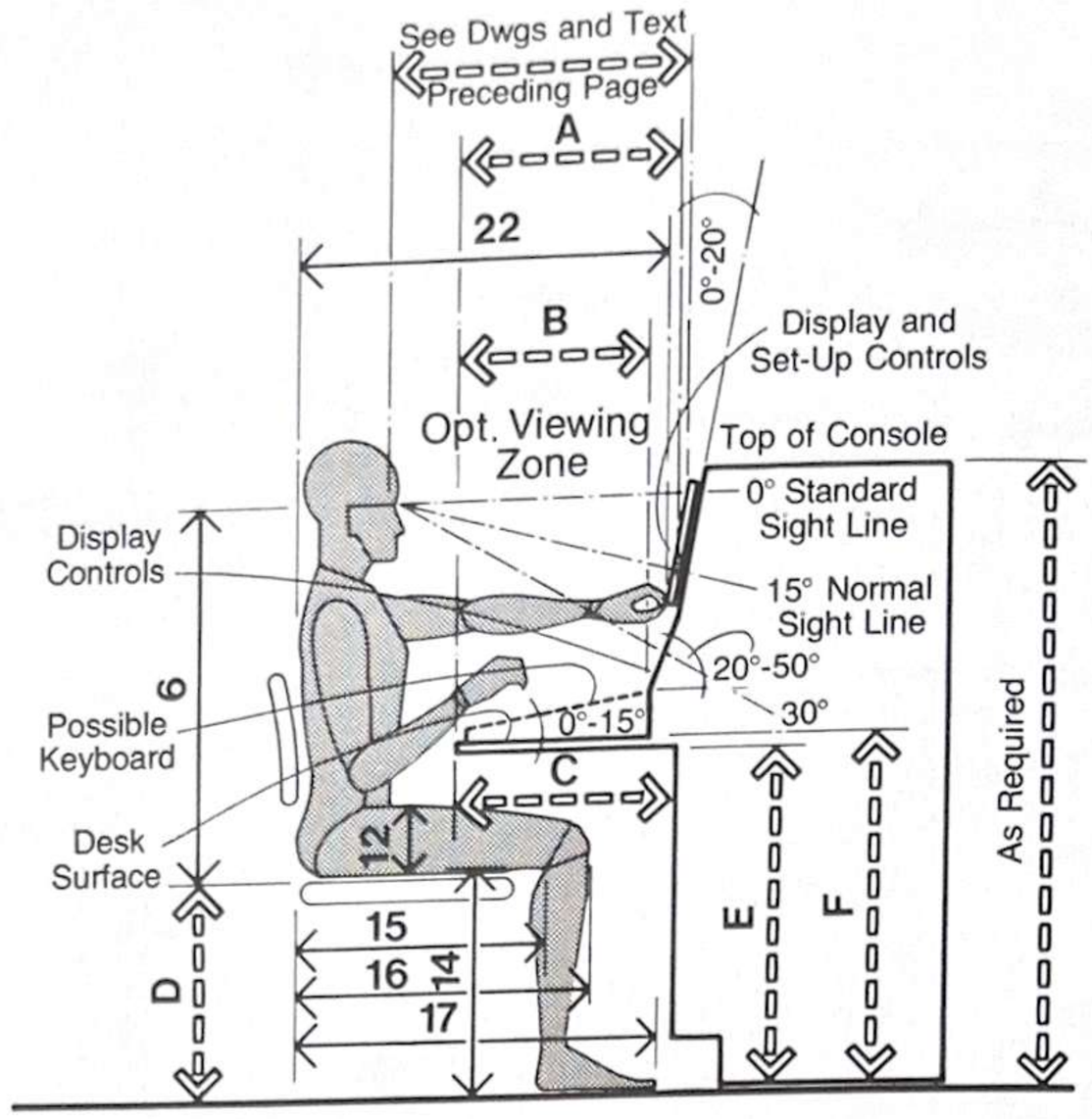
Controls

Controls should be placed within reach of the smaller viewer and located so that the body movement necessary for operation of the controls will not obstruct visibility.

	in	cm
A	28–29	71.1–73.7
B	18–22	45.7–55.9
C	13–16	33.0–40.6

9.2 WORKSTATION DISPLAYS

The top drawing illustrates guidelines for use in establishing preliminary design assumptions for a workstation display console. Since the types of displays and the nature of the tasks associated with those displays can vary considerably, the drawing cannot be taken too literally. The configuration shown, however, is fairly representational. Certain basic factors should be noted anthropometrically. The use of an adjustable chair will permit the eye height of the seated viewer to be raised or lowered to view the display, as may be required depending on body size. An adjustment range between 15 and 18 in, or 38.1 and 45.7 cm, should be adequate to accommodate the eye height sitting requirements of about 90 percent of all viewers. Adjustability, however, will be of little value if the vertical distance between the underside of the desk and the floor is insufficient to accommodate the knee height and thigh clearance when the seat is adjusted to the appropriate position. If such distance is not less than 26.5 in, or 67.3 cm, the majority of viewers will be accommodated.



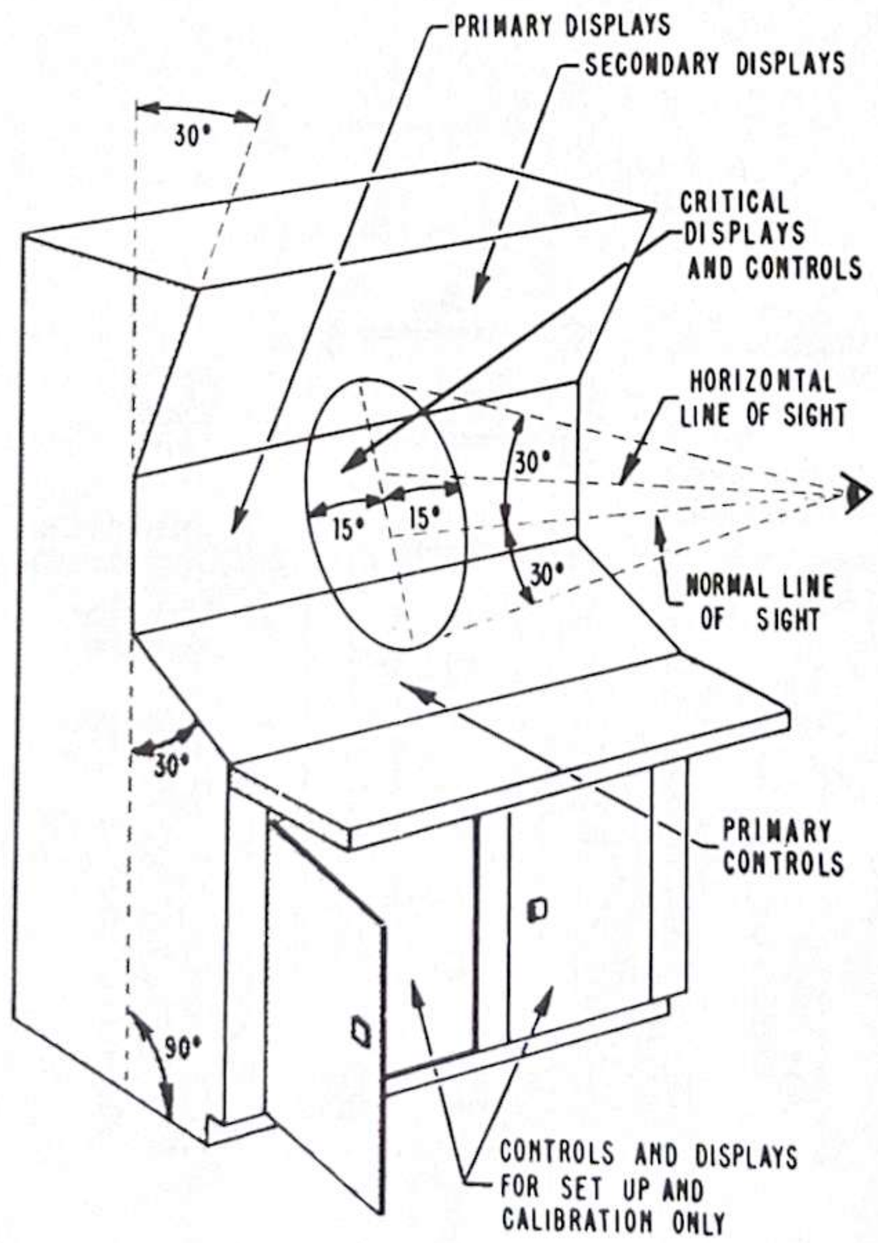
DESIGN GUIDELINES/ WORKSTATION DISPLAY CONSOLE

Adapted from *Human Engineering Guide to Equipment Design*, p. 393.

The location of the top of the display should align with the standard sight line for optimum viewing conditions. Since the eye and the head can rotate within certain limitations and, in so doing, increase the area that can be scanned, displays can be located above the standard sight line when absolutely necessary. It should also be noted that the more perpendicular the normal sight line is to the display plane, the greater the viewing comfort. Accordingly, consideration should be given to sloping the display plane since the normal sight line is about 15° below the horizontal.

The drawing at the bottom is from another source and stresses many of the angular relationships involved in display console design.

	in	cm
A	16–18	40.6–45.7
B	16 min.	40.6 min.
C	18 min.	45.7 min.
D	15–18 adjust.	38.1–45.7
E	26.5 min.	67.3 min.
F	30	76.2



RECOMMENDED POSITIONING OF CONTROLS AND DISPLAYS ON VERTICAL SEGMENT CONSOLES

From *Human Factors Engineering*,
U.S. Air Force Systems Command Handbook DH 1-3, P.DN2E5, 4.

9.3 DISPLAYS FOR GROUP VIEWING

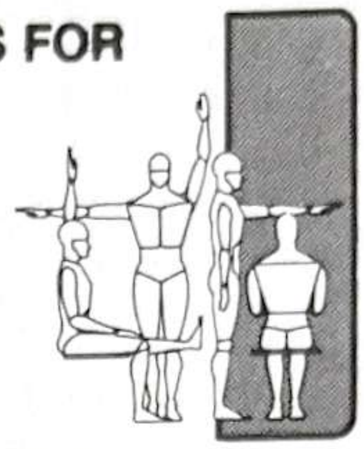
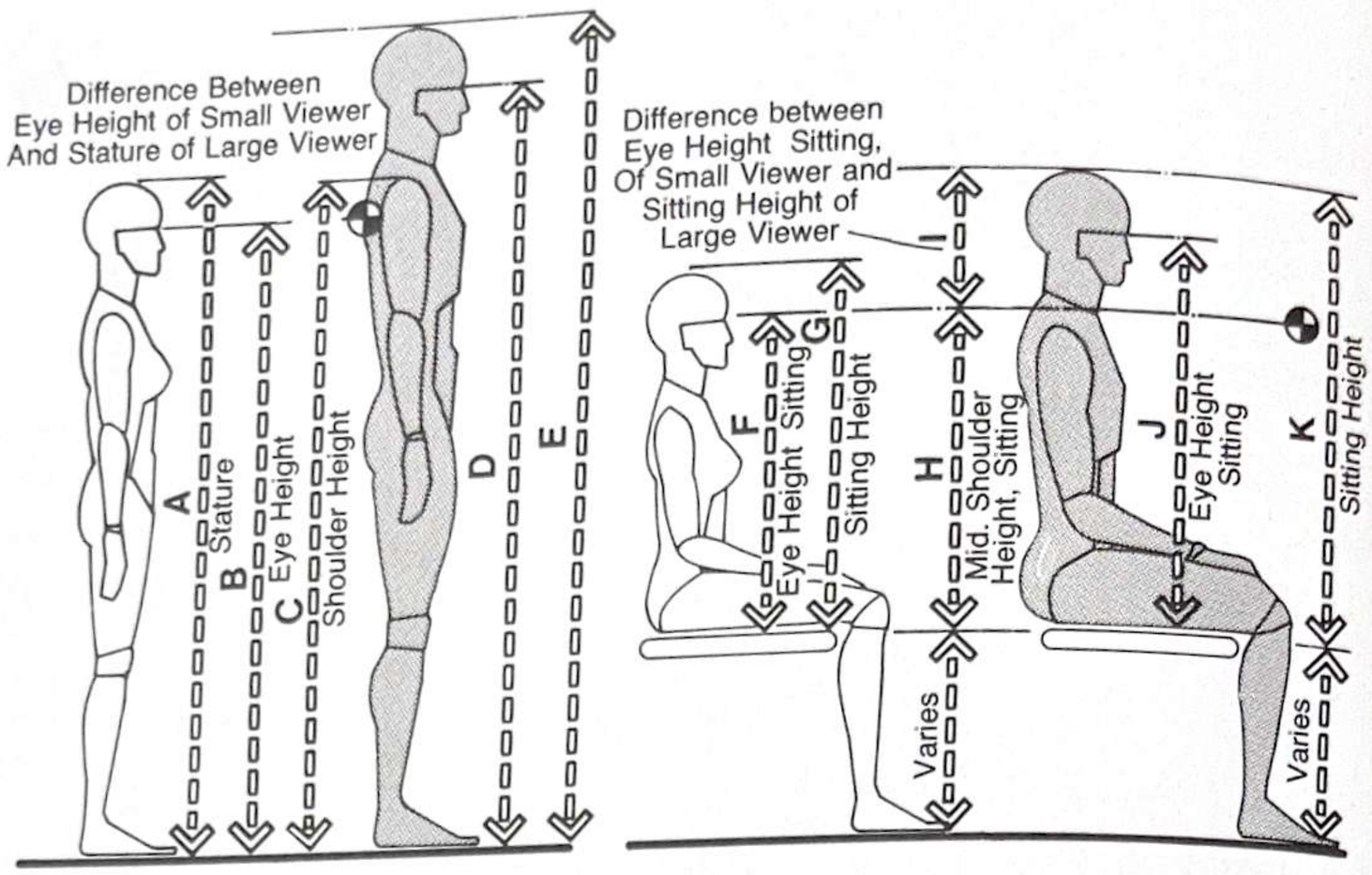


TABLE	SEATED VIEWING	STANDING VIEWING	SPEAKER	ACTIVITIES	ANTHROPOMETRIC DATA
1A,2B			◪	1	STATURE
1B,3C		◪	◪	2	EYE HEIGHT
1C,3B			◪	3	ELBOW HEIGHT
1E,2D	◪			5	SITTING HEIGHT NORMAL
1F,3G	◪			6	EYE HEIGHT SITTING
1N,2J	◪			14	POPLITEAL HEIGHT
1O,2K	◪			15	BUTTOCK-POPLITEAL LENGTH
1P,2L	●			16	BUTTOCK-KNEE LENGTH
1Q,3F	●			17	BUTTOCK-TOE LENGTH
1W,6B	●		●	23	MAXIMUM BODY DEPTH
1X,6A	●			24	MAXIMUM BODY BREADTH
	●			28	ECTOCANTHUS TO TOP OF HEAD

Visual communication systems for group viewing present somewhat different problems than those normally associated with systems designed for the individual viewer. Ideal displays for the latter are located so the viewing angle is generally below the horizontal line of sight. However, due to the size and relationship of a group display, such as a projection screen in a motion picture theater, to the viewer and the obstruction of the visual field of one viewer by another, the display is located so that the upper limit of the optimum viewing angle is situated above the horizontal line of sight. The general layout and configuration of the seating must be planned to ensure the greatest visibility for the greatest number. The minimum distance the front row of seats can be from the display to allow adequate viewing must be considered in the planning of the interior space and general seating layout. Seats must be planned to allow sight lines of one viewer to pass above and between the viewer in front. The distance between rows must allow adequate clearance for circulation and human movement. Provisions for the disabled or wheelchair-bound viewer must also be taken into account. In live situations, a lectern, pulpit, or bimah and the speaker all must be considered as part of the communication system. The design of the lectern should respond to the anthropometric and visual requirements of the speaker. In addition, the lectern-speaker as the display should bear the proper visual relationship to the viewers. The drawings that follow explore various aspects of the group viewing process and suggest clearances and other data for use in preliminary design studies.

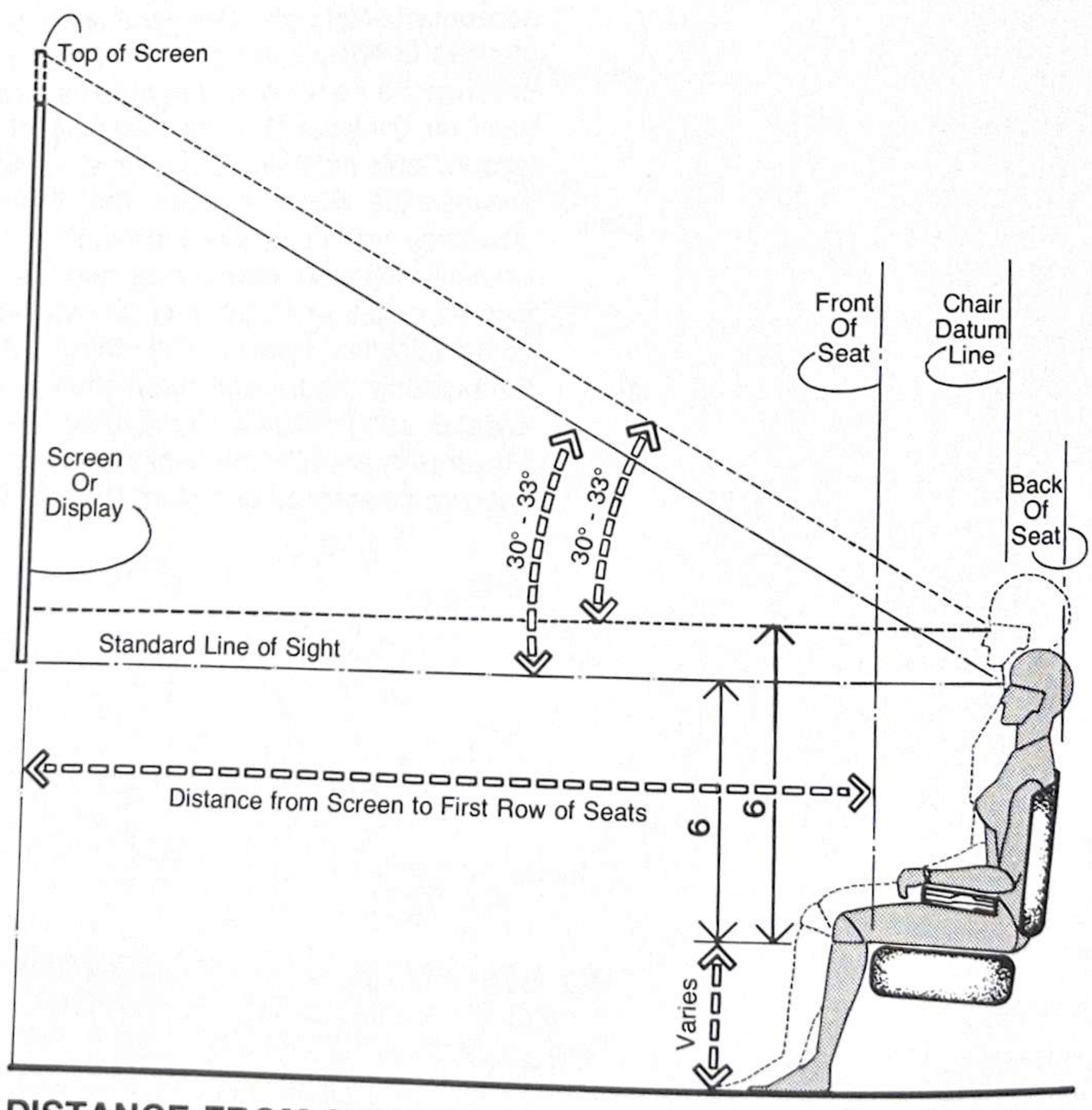
9.3 DISPLAYS FOR GROUP VIEWING

The design of spaces for group viewing activities requires some knowledge of the anthropometrics of the tall and short standing and seated viewer and the visual implications involved. The top drawing shows that the basic 5th percentile and 95th percentile body measurements of standing viewers are such that the line of sight of the shorter viewer would be obstructed by the taller viewer. When the same 5th and 95th percentile measurements are applied, the drawing of the seated viewers indicates that the line of sight of the smaller viewer just clears the midshoulder height of the larger viewer in front. It should be noted that the difference in eye height between the larger and smaller seated viewers is about half the difference in eye height when the larger and smaller viewers are standing. The minimum distance between the first row and the display can be determined by drawing a sight line from the top of the projected image to the eye of the viewer seated in the first row at an angle not less than 30° nor more than 33°, as indicated in the bottom drawing.



COMPARATIVE ANTHROPOMETRICS/ STANDING AND SEATED VIEWERS

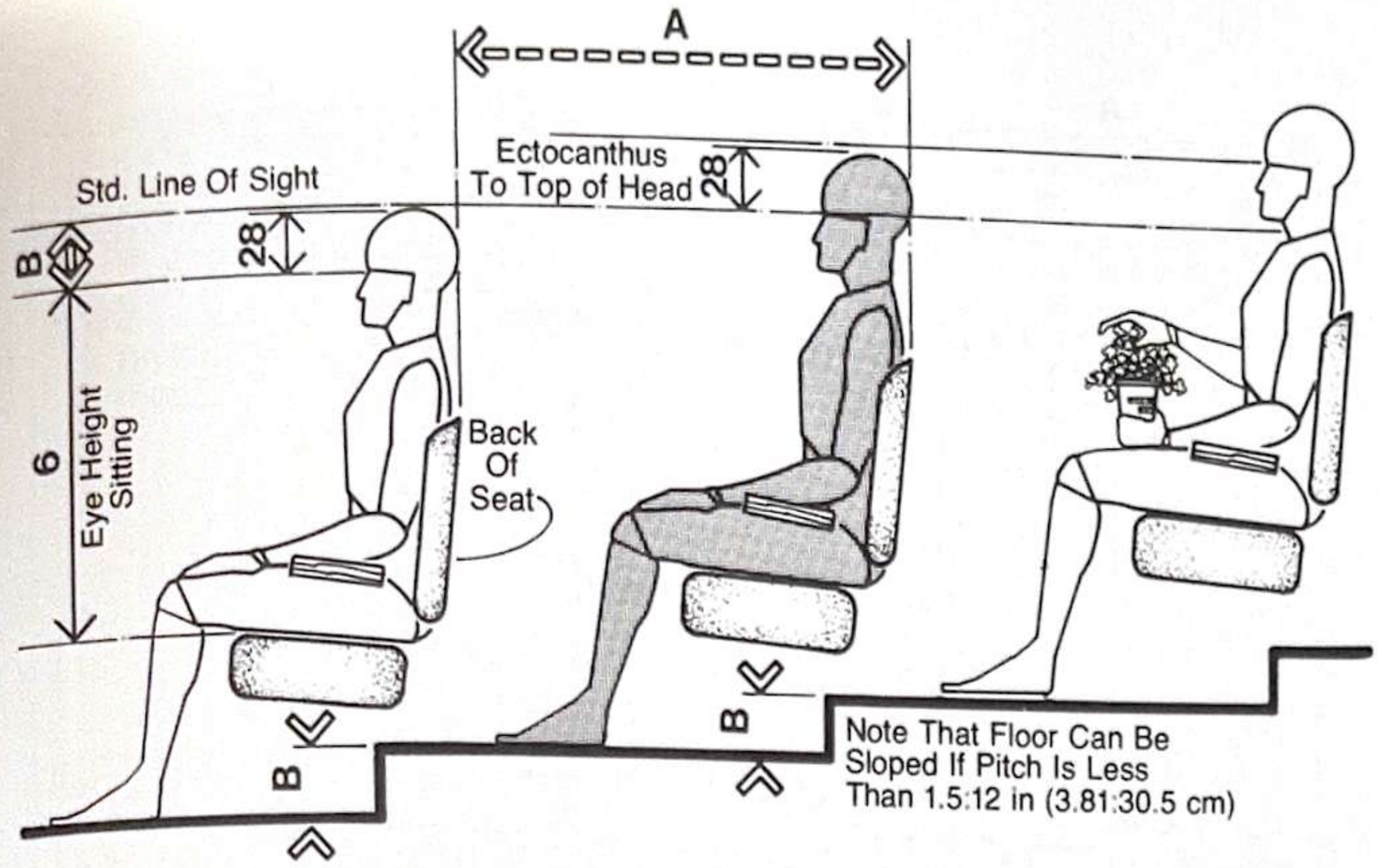
	in	cm
A	59.0	149.9
B	56.3	143.0
C	57.8	146.8
D	68.6	174.2
E	72.8	184.9
F	28.1	71.4
G	29.6	75.2
H	27.3	69.3
I	9.3	23.6
J	33.9	86.1
K	36.6	93.0



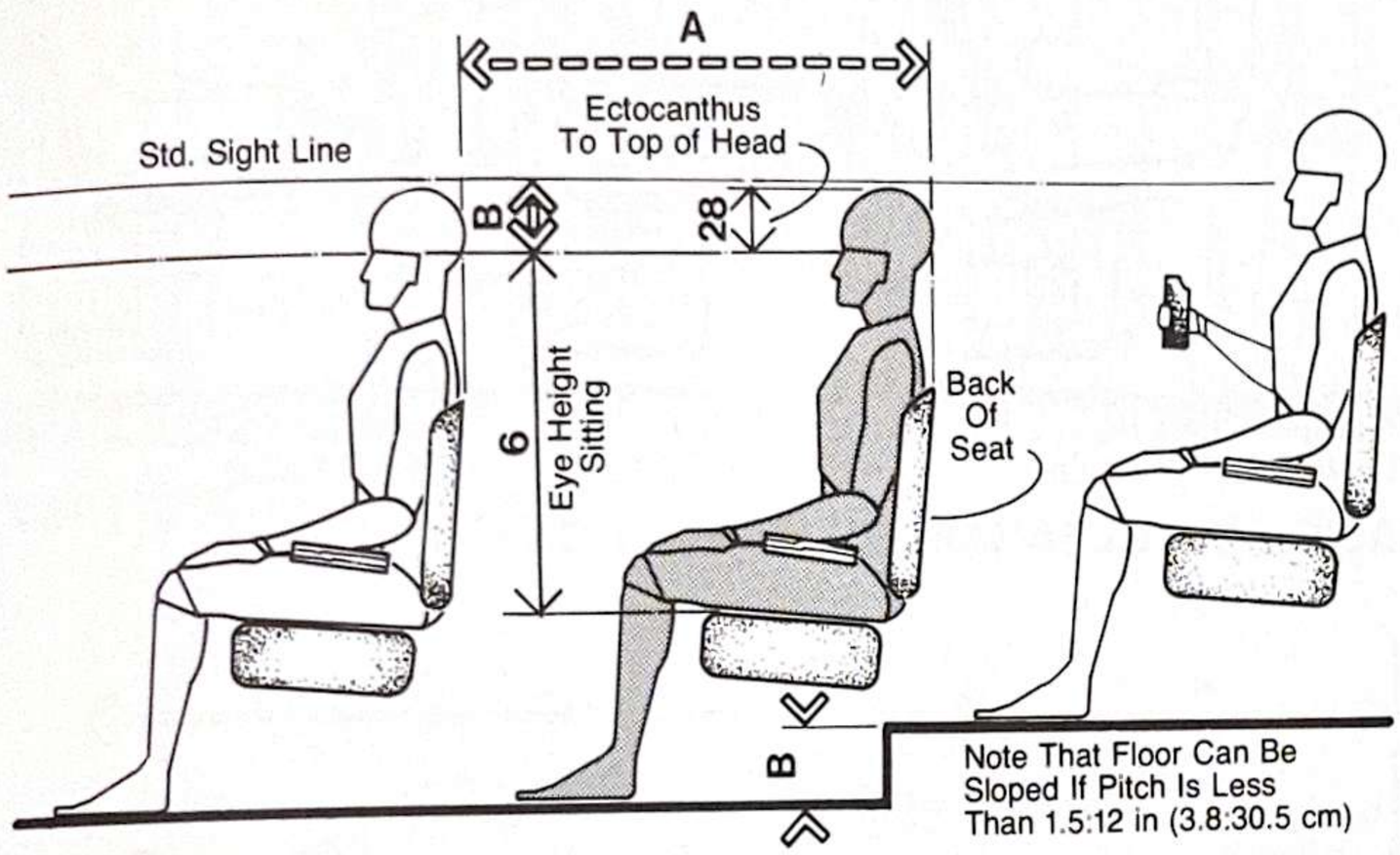
DISTANCE FROM SCREEN TO FIRST ROW

9.3 DISPLAYS FOR GROUP VIEWING

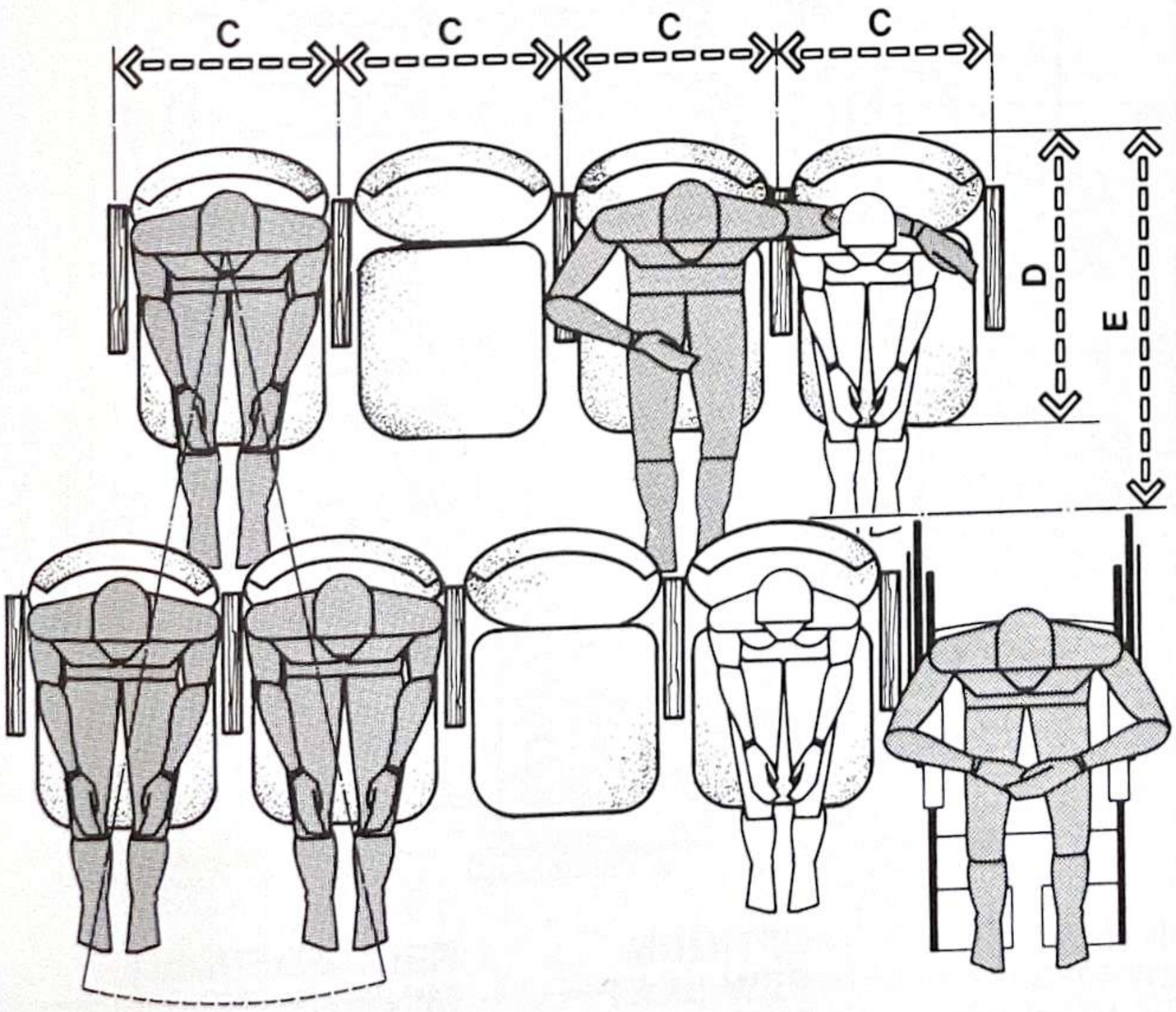
Maximum visibility for the greatest number of seated viewers can be achieved by elevating their eye heights successively from front to back row so that one viewer can look over the head of the person in front. The ectocanthus to top of head measurement is the anthropometric data most useful in determining the actual height by which the floor must be stepped or sloped to achieve this condition. It is the distance from the outer cornea of the eye to the level of the top of the head. The 95th percentile data shows this measurement to be about 5 in, or 12.7 cm, and is the increment by which the floor is stepped. The top drawing illustrates the "one-row vision" method of elevating eye heights so that the viewer may have unobstructed vision over the heads of those viewers in rows immediately ahead. The center drawing illustrates the "two-row vision" method which prevents the heads of all viewers two or more rows ahead from blocking visibility. The advantage of this method is that it minimizes the slope or number of steps. Its disadvantage is that it is not as effective as the one-row scheme. Wider seats and a staggered plan, however, can improve visibility by permitting a view between the heads of those directly in front, as shown in the bottom drawing. In regard to the depths of rows, although a 32-in, or 81.3-cm, spacing is often used, 40 in, or 101.6 cm, is recommended.



STEPPED SEATING / ONE-ROW VISION



STEPPED SEATING / TWO-ROW VISION



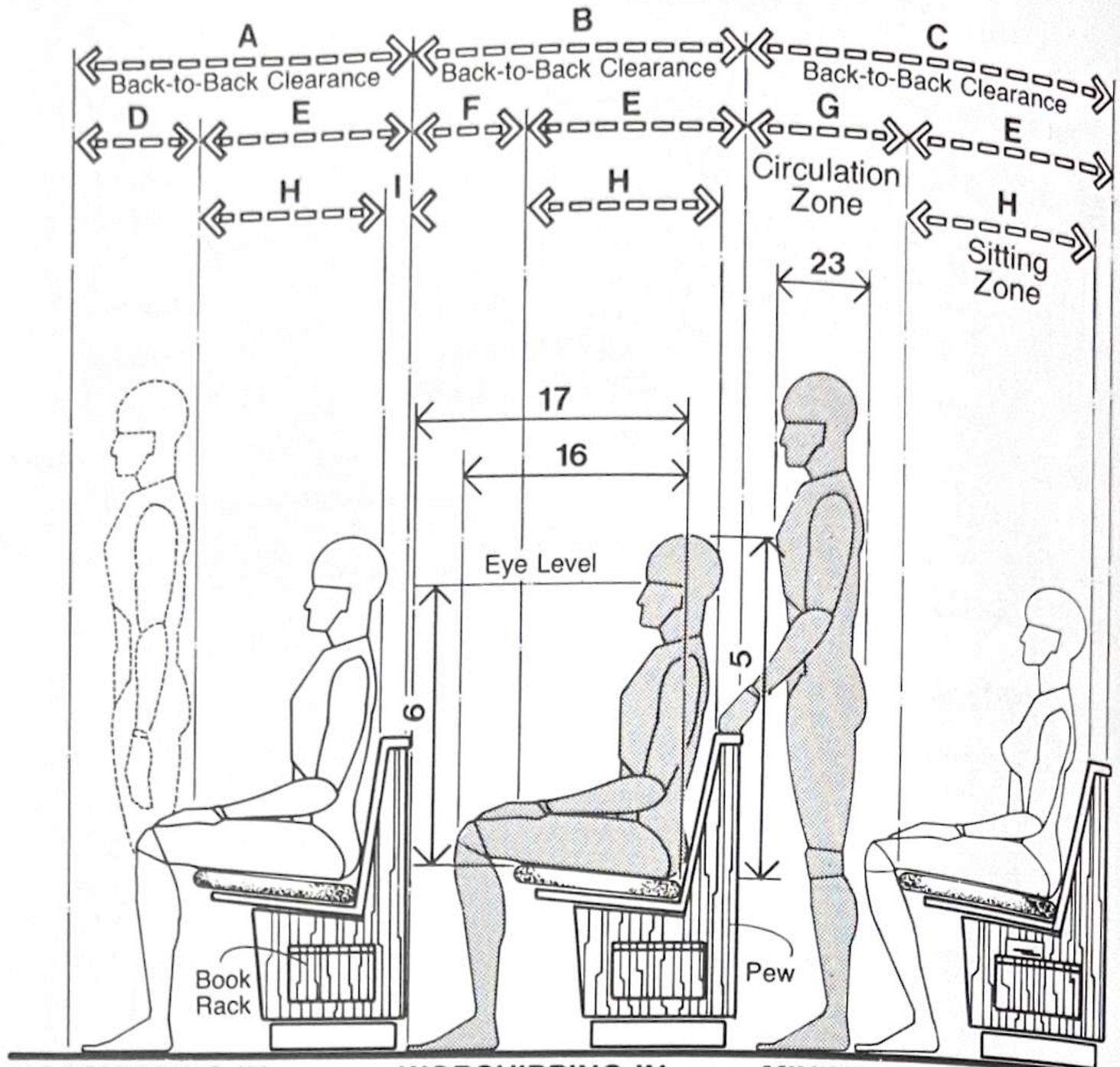
STAGGERED SEATING

	in	cm
A	40	101.6
B	5	12.7
C	20–26	50.8–66.0
D	27–30	68.6–76.2
E	34–42	86.4–106.7

9.3 DISPLAYS FOR GROUP VIEWING

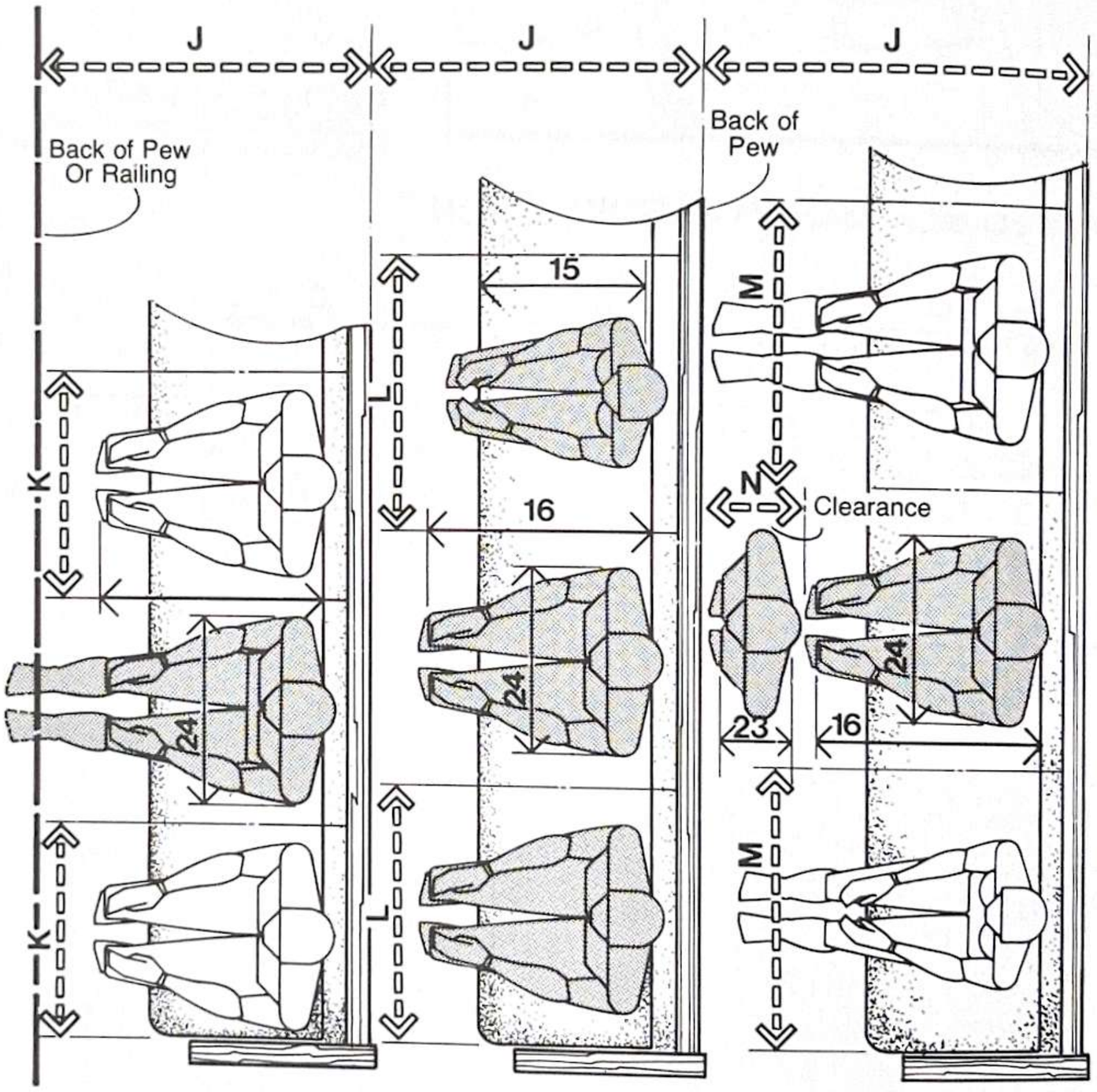
Unless traffic flow to the pew is controlled, the lack of armrests makes the seat allowance shown in the top drawing somewhat theoretical. Assuming some controlled means of seat space definition, however, a reasonable incremental unit to use as a basis for seat width is the maximum body breadth. The 95th percentile data for larger users is 22.8 in, or 57.9 cm, taken with the subjects nude. The top drawing shows three possible seat allowances: 24 to 26 in, or 61 to 66 cm; 28 in, or 71.1 cm; and a possible minimum of 22 in, or 55.9 cm.

When one considers that an allowance for clothing and ritual-related body movement should be added to the 22.8 incremental unit, the 22-in minimum would not comfortably accommodate the majority of users without some body contact. Economics permitting, the 28-in spacing is recommended. The bottom drawing shows several pew spacing possibilities. All can work, depending on the level of comfort desired and the nature and frequency of ritual-related body movements.



WORSHIPPING IN STANDING POSITION | WORSHIPPING IN SEATED POSITION | MINIMUM CIRCULATION CLEARANCE

BASIC PEW CLEARANCES / ELEVATION



MINIMUM PEW SEAT PER PERSON

OPTIMUM PEW SEAT PER PERSON

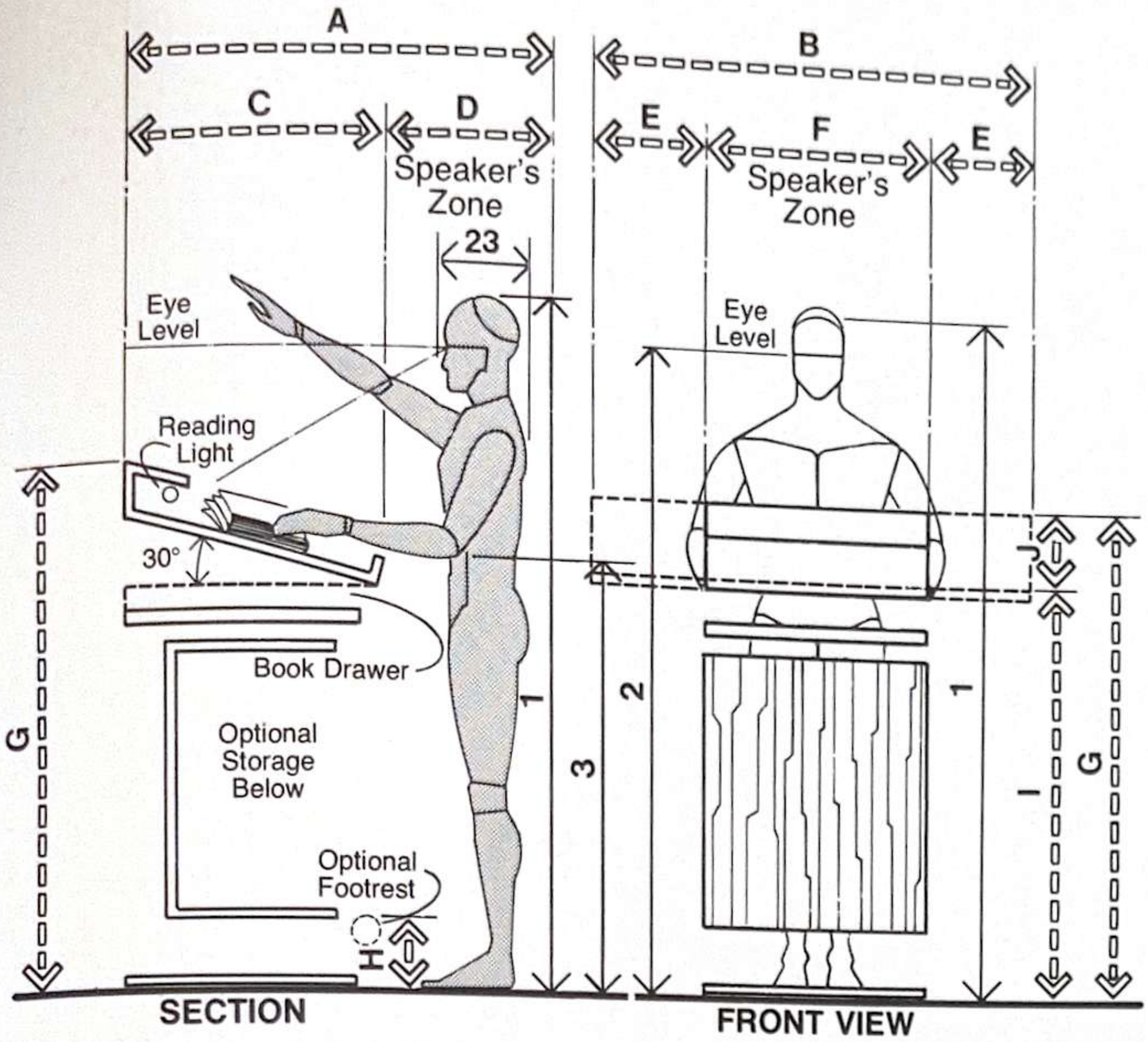
RECOMMENDED MINIMUM PEW SEAT PER PERSON

	in	cm
A	34–38	86.4–96.5
B	34–36	86.4–91.4
C	42–48	106.7–121.9
D	12–16	30.5–40.6
E	22	55.9
F	12–14	30.5–35.6
G	20–26	50.8–66.0
H	20	50.8
I	2	5.8
J	42	106.7
K	22 min.	55.9 min.
L	24–26	61.0–66.0
M	28	71.1
N	14–18	35.6–45.7

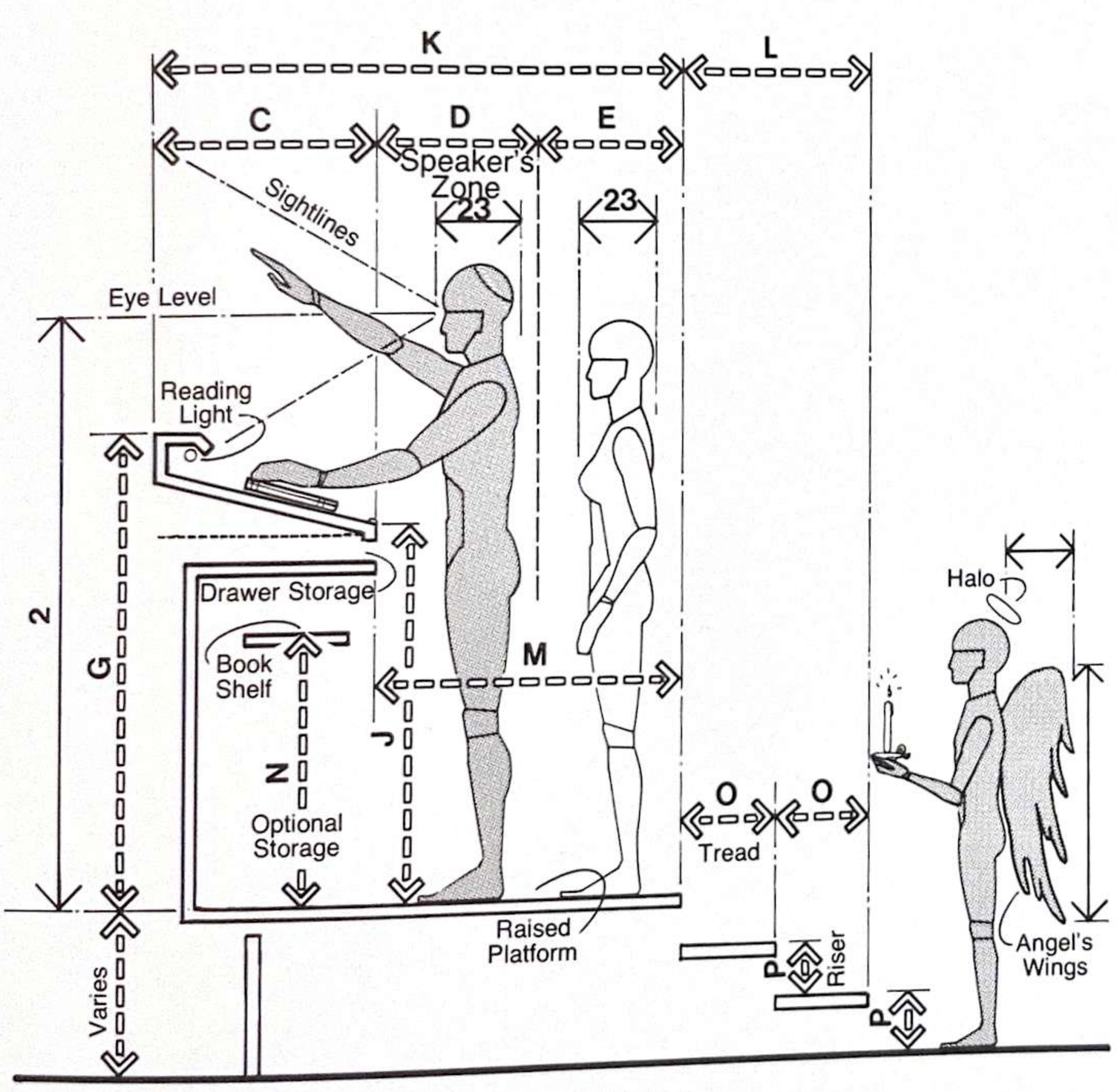
9.3 DISPLAYS FOR GROUP VIEWING

When an audience is listening to live speeches, lectures, or sermons, the lecturn, pulpit, or bimah and the speaker should be viewed as the display. With respect to the speaker, the display is assumed to be whatever notes or other written material he may use in connection with his delivered presentation. The top drawing shows some of the basic dimensions involved and suggests some of the visual and anthropometric considerations implied. For optimum speaker viewing comfort, the surface upon which notes are placed should be at an angle of about 30°. When anthropometrically determining the height of the top of the lecturn surface facing the speaker, elbow height should be taken into account. The extent to which the lecturn may obstruct both viewer and speaker vision should also be considered.

Visibility for the viewers in the first row is also extremely important. The bottom drawing indicates a raised lecturn situation. As with any platform, safety provisions should be built into the design.



LECTURN, PULPIT, OR BIMAH



	in	cm
A	42–66	106.7–167.6
B	48–66	121.9–167.6
C	24–42	61.0–106.7
D	18–24	45.7–61.0
E	12–18	30.5–45.7
F	24–30	61.0–76.2
G	45–50	114.3–127.0
H	4–8	10.2–20.3
I	36–39	91.4–99.1
J	7–10	17.8–25.4
K	60–90	152.4–228.6
L	22–28	55.9–71.1
M	36–48	91.4–121.9
N	29–32	73.7–81.3
O	11–14	27.9–35.6
P	6–7	15.2–17.8

RAISED LECTURN, PULPIT, OR BIMAH

D EPILOGUE

EPILOGUE

NASA is presently planning a space vehicle that will "carry large numbers of people of all nations and races, and of a wide range of body sizes and ages, into and out of weightlessness." It is anticipated that such a transportation system will be followed by "space stations where people will function for long periods, in an environment for which their bodies were not designed." In regard to the design process involved in this massive scientific undertaking, scientist-astronaut Dr. William Thorton writes:

> The quality of the interface which connects man with his machines frequently determines the ability and the ultimate performance of the man-machine unit. . . . The beginning of any man-machine interface is the objective knowledge of the full range of man's size, shape, composition and mechanical capabilities.[1]

Apparently, Dr. Thornton has applied a concept that many of us, as earthbound designers of interior space, for too long have failed to recognize. It is ironic that, as designers involved deeply in situations where the quality of people's interface with the physical environment is paramount, we have, as a profession, failed in our awareness, exploration, understanding, and application of engineering anthropometry—the most basic aspect of that interface.

In the research, writing, and general preparation of this book, we found ourselves both stunned and frustrated at the lack of anthropometric data generally available for use by architects and interior design professionals—professionals who are primarily responsible for the total design of the interior spaces in which people live, work, and play. The frustration was compounded when we observed other professionals, to their credit, impressively involved in the development and application of anthropometric data to the design of equipment and man-in-space environments at a time when the term itself was still relatively foreign or unfamiliar to the majority of us in the interior design and architectural professions. With a few exceptions, we have as a group remained far too passive, when, in fact, by the very nature of our professional mission, we should have been at the forefront of the research in this area. As a consequence we have found that too much of what is being designed today is still based on unchallenged and outdated standards, rules of thumb, intuitive judg-

ments, antiquated trade practices, and manufacturer's recommendations, many of which are insensitive to human factors, in general, and body size and dynamics, in particular. We feel it is incumbent upon the design professions to take immediate action in this area and look forward to the time when architectural anthropometry may possibly develop into a discipline in itself or, at the very least, constitute a basic part of the educational process for interior designers and architects.

Undoubtedly, many may question the level of importance we have placed on the study of body size and human dimension as it relates to interior design and architecture and the sense of urgency we have placed on the accumulation of necessary anthropometric data. Although body size would understandably be an important factor in the design for the cockpit of a fighter aircraft or the limited confines of a space vehicle in zero-gravity, some may argue that problems of fit within typical civilian environments are not as critical and that to apply such an approach to the design of civilian interiors would be like going after a mouse with an elephant gun.

Although military and aerospace design applications of anthropometric data may well involve more and different body measurements and in some instances the tolerances of fit may be more critical, many of the applications have equivalent civilian counterparts. More importantly, however, we want to emphasize that an improper fit between the individual and his environment, whether that environment is in the military, aerospace, or civilian sector, can impact dramatically not only on his comfort but on his personal safety. In some instances the quality of that interface can, in fact, be a matter of life and death.

To reinforce that statement, we must lay out certain facts and misconceptions we have uncovered, as well as insights we have gained, during the research for this book over the past two years. Some of this material may have been implied in previous sections of the book, while some may have been discussed in somewhat greater detail, and certain material may not have been mentioned at all. We hope it will all serve to underscore the present and very real danger faced by the user in his interface with those components of interior space designed without regard to human dimension and, at the very least, the urgent need for additional research and reevaluation of many of the questionable practices and standards in circulation today.

The most shocking information uncovered during the course of our research involves children. A recent study indicated that the death rate of children under one year of age from accidental suffocation related to beds and cradles was 18.6 per 100,000 live births in 1965. The implication is that a strong relationship exists between improperly designed furniture and accidental death and injury. Other studies imply that improper spacing of slats in cradles and playpens, which would permit an infant's head to pass through, is the cause of many of the fatalities—a clear, although painful, example of the importance of human dimension in the design process. Within a larger context, the chilling statistics from the Consumer Product Safety Commission are that upwards of 2 million children are injured each year in accidents attributed to toys, playground equipment, bicycles, and other children's products. One can only speculate how many of

these accidents are caused by the designer's insensitivity to human dimension and the poor quality of the user-product interface. So critical was the problem and so essential to its solution was anthropometric data that the Consumer Product Safety Commission funded a three-year study, the major purpose of which was to provide basic selected measurement data on infants and children, particularly functional measurements, essential for the development of adequate product safety design standards.

Perhaps the greatest misconception we became aware of is the notion of the so-called average man. There has been a tendency on the part of those engaged in shaping our interior spaces to design to accommodate the average user and, by extension, to mistakenly assume that in so doing they are accommodating a majority of those users. The reality is that no such human being exists. So-called average dimensions are simply statistical means indicating that in the sample population whose body measurements were recorded, about 50 percent had a specific body measurement of a particular dimension or less. Obviously, any design based on the accommodation of such data would, in most instances, exclude at least 50 percent of the users—a far cry from the majority the designer had originally intended to accommodate.

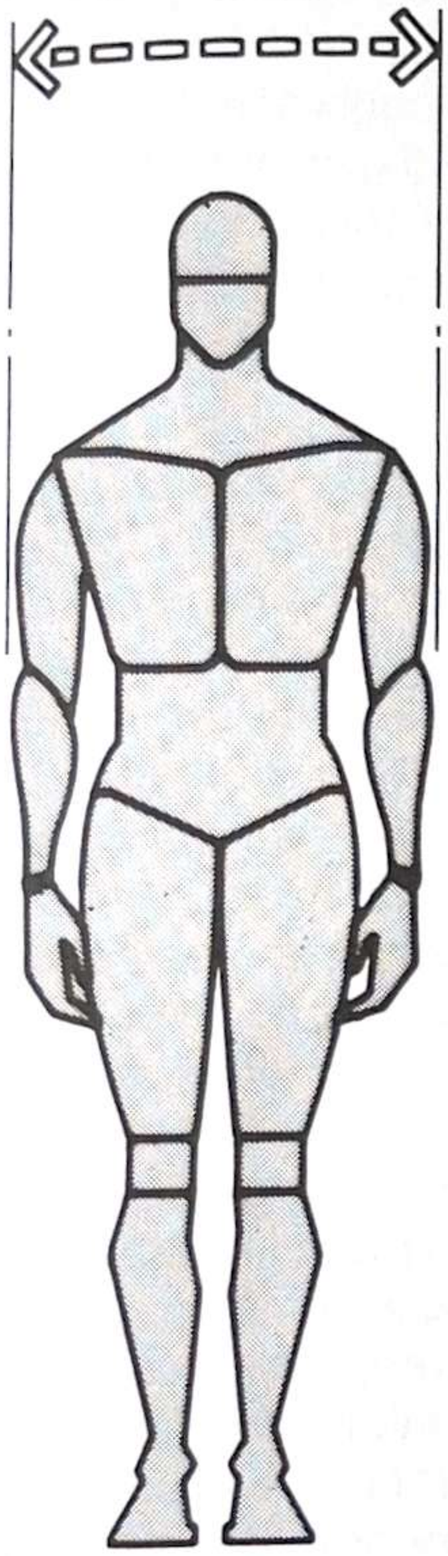


Figure E–1. Maximum body breadth.

Moreover, no person is average in all his body dimensions. He simply is not built that way. This has been demonstrated by studies made of the middle range of a sample of 4,000 males, which showed that of ten body dimensions measured, only 25 percent were average in a single dimension and less than 1 percent were average in five dimensions. Despite this, we are constantly exposed to literature suggesting designs to suit the average user. In addition, what little body size data has heretofore been made available to us proudly declares that the dimensions are that of an average person. To further compound the error, the same data, usually in the form of a dimensioned figure, are not limited to a single body measurement, but a host of measurements. The human body, as indicated earlier, is simply not proportioned so that all body measurements are average.

Another misconception, the perpetuation of which could impact on personal safety, if not comfort, deals with a very basic body dimension, that of maximum body breadth, illustrated in Figure E-1. Maximum body breadth is measured with the nude subject standing erect and with arms hanging relaxed at the sides. The dimension reflects the horizontal maximum breadth across the body including the arms. We decided to consult published anthropometric data to determine what the range of dimensions were in regard to this particular body measurement. Based on a study by Hertzberg, Emanuel, and Alexander in 1956, the 5th, 50th, and 95th percentile data were 18.8 in (47.8 cm), 20.9 in (53.1 cm), and 22.8 in (57.9 cm), respectively. Adding an allowance for winter outer clothing of 3 in, or 7.6 cm, and rounding off increased the figures to 22 in (55.9 cm), 24 in (61.0 cm), and 26 in (66.0 cm), respectively. The startling revelation in this data can only be fully appreciated when compared with what the actual maximum body breadth allowances are in the various design standards in circulation regarding corridor widths, door widths, spacing of plumbing fixtures, and motor stair widths, to list only a few.

For example, many local, state, and national codes, in establishing requirements for corridors, passageways, and walkways, use a 22-in, or 55.9-cm, incremential factor. The underlying implication is that 22 in, or 55.9 cm, represents the dimension required to accommodate an additional pedestrian lane. Two additional lanes would require a total of 44 in, or 111.8 cm. According to anthropometric data, however, only 5 percent of the users would have a clothed maximum body breadth of 22 in, or 55.9 cm, or less. Further research revealed that certain other studies concerned with walking patterns and gait indicated that the human body sways from side to side a distance of about 4 in, or 10.2 cm, making 22 in, or 55.9 cm, even more inadequate. A so-called two-lane motor stair has a maximum width at rail height of 48 in, 121.9 cm, tapering to a 40-in, or 101.6 cm, clearance at the tread. Allowing for the taper and recognizing that the body position of the passenger is dictated also by the location of his foot in relation to the side of the stair, we again found that only those passengers with the smaller range of body sizes would, in fact, be accommodated.

Another rule of thumb presently circulating and actually suggested by manufacturers is the center-to-center spacing of lavatories at 24 in, or 61.0 cm. How many of us, in laying out public restrooms, have unquestioningly applied this standard? During the course of our research, we decided to test the validity of such spacing. An application of anthropometric logic proved the spacing to be inadequate. The maximum clothed body breadth measurement of 26 in, or 66.0 cm, clearly indicates an error. A battery of lavatories spaced according to the standard simply would not permit the user, with a larger body size, access to a fixture without displacing the person next to him. It should be noted, however, that maximum body breadth measurements are taken with the subject's arms at his sides, while actual use of the lavatory requires the arms to be extended out from the body, thus increasing the space required in front of the fixture and making the 24-in, or 61.0-cm, spacing even more inadequate. Actually, less than 50 percent of the users can be accommodated by such a spacing standard—hardly a reasonable range of accommodation for a public facility subjected to intense peak loads. It would seem that the spacing requirement was based more on accommodating the maximum number and sizes of lavatory types than the number and sizes of the users it was supposed to serve.

A similar problem, for similar reasons, applies to recommended spacing for urinals, except that due to the nature of the activity involved and even more restricted spacing, the standards are even more inadequate. Present rules of thumb, as well as actual manufacturer's recommendations, suggest spacing urinals, placed in a battery arrangement, between 21 and 24 in, or 53.3 and 61.0 cm apart. Given the maximum clothed body breadth dimension of 26 in, or 66.0 cm, cited previously, the absurdity of such a spacing becomes obvious. Curiously, most sanitary codes dictate the minimum number of plumbing fixtures deemed acceptable, but do not specify any requirements for minimum spacing. The designer may comply with the language of the code, but by not questioning the anthropometric implications, not its intent, since less than 50 percent of the users could actually have access to the fixtures under peak load situations without body contact.

On balance, it would appear that present standards allow the manufacturer the greatest number and variety of his products to be installed in the smallest space possible and the building owner to reduce construction costs and maximize rental area while still complying with code requirements—all at the expense of the user and the quality of his interface with the interior environment. We conclude that most currently used design guidelines which presumably should reflect people's maximum body breadth dimensions, simply cannot be reconciled with published anthropometric data and that the designs evolving from those guidelines are simply unacceptable. Anyone who has used the crowded restrooms at an airport, sports stadium, or bus terminal has observed the percentage of fixtures left unoccupied, despite the great number of people waiting in line to use the facilities. How often have you actually seen two people abreast facing the same direction in a so-called two-lane motor stair or walking through a 44-in, or 111.8-cm, opening? Very infrequently. The reason is quite simple: more often than not they simply cannot fit.

It should be noted that our arguments with present clearance allowances is exclusively anthropometric. In order to present the most conservative argument possible, we did not mention the hidden dimensions. Surely the body buffer zone (and the personal space implied), particularly with respect to the planning of public toilet facilities, should be considered. The fact that people will walk so close to a wall and no closer should be a factor in determining clearances. Human gait and cultural influences also affect clearance allowances. Personal comfort and the quality of life surely are other ingredients to consider. If all these considerations are taken into account, as they should be, present clearance allowances become even more inadequate.

And what of personal safety? In many cases where inadequate standards are used, the larger width of a certain opening, walkway, or stairs, relative to the smaller width of similar openings, walkways, or stairs, may suggest double lane traffic, when, in fact, two lanes cannot be accommodated. The user whose sensory mechanism may not be sophisticated enough to anticipate the inadequacy will attempt entry into the perceived second lane. It is almost inevitable that body contact with the adjacent pedestrian will result, or one of the two will be obliged to side step to allow the other to pass. Either eventuality may result in an accident. During crowded conditions or an emergency such an accident could prove fatal. More serious still would be a situation where a two-lane pedestrian traffic flow was essential to evacuate a specified number of occupants from an interior space of public assembly within a certain period of time. If incorrect maximum body breadth data were used in determining the width of the corridors, passageways, or stairs involved, it could result in a disaster.

We also discovered that present standards for tread-riser relationships are to a large degree based on antiquated rules of thumb. Many codes today still utilize an empirical formula that originated almost four centuries ago. Some of the few studies made recently, both in this country and abroad, indicate that many stair designs and standards simply are not responsive to the anthropometric requirements involved. Present minimum tread dimension requirements in circulation do not provide enough contact surface to accommodate

the larger range of maximum shod foot length. Our own limited investigation suggests that where conditions permit a 6.8-in, or 17.3-cm, riser and an 11.3-in, or 28.7-cm, tread relationship maximizes both comfort and safety and that a riser height of 7 in, or 17.8 cm, or more should be avoided if at all possible. When one considers that somewhere in the neighborhood of 4,000 stair-related fatalities take place each year, the need for additional research in this area becomes painfully evident.

While we are hopeful that this book will, to some degree, be helpful in making the designer aware of the importance of human dimension in the design process and in establishing a link between the discipline of engineering anthropometry and the architectural and interior design professions, it is a very modest beginning. There is much we must do and much we need to know.

- We must first fully grasp the fundamentals and significance of engineering anthropometry so that we can engage the anthropometrist in intelligent discussion in order to define our needs.
- We must press for appropriate anthropometric data concerning the civilian population generally, since most of the present information involves the military.
- We must also develop an inventory of data concerning specific groups within the civilian sector, such as children, elderly people, and physically disabled people.
- We must encourage research at the university level and by independent design professionals and firms through professional societies and government and private foundation grants. Studies of the human body in motion should be high on the list of priorities.
- We must begin to question existing standards and guidelines.
- We must insist that anthropometry be included in professional architectural and interior design curricula.
- As the largest specifiers of residential and contract furniture and other components of interior spaces, we must demand from the manufacturers of these products the highest quality of product-user interface. We must encourage the manufacturer to reevaluate product design in terms of responsiveness to human dimension, body size, and corresponding variability. The degree to which elements of interior space can be adjusted should be investigated.
- To implement the foregoing, a committee should be created within the professional design organizations. Lines of communication should be established with the anthropometrist, the educational community, the manufacturer, the architect, and the interior designer. A clearing house for data and research of interest to the designer should be created. Lecture series dealing with anthropometry should be initiated.

To conclude on an optimistic note, perhaps one of the most encouraging developments with respect to the availability of anthropometric data on civilian populations came about during the writing of this book. It has long been contended that the degree to which military data could be applied to civilian design situations was relatively lim-

ited. In a paper delivered at the meeting of the American Psychological Association in August 1978, Charles Clauser of the AeroSpace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, and Dr. John McConville of Anthropology Research Projects, Inc. of Yellow Springs, Ohio, suggested that military data may have a far greater level of applicability to nonmilitary situations than previously thought. They stated that

> Although relatively fewer and smaller surveys have been conducted on civilian subjects, it can be demonstrated that large segments of the military and civilian populations of the U.S. are comparable in body size and it is our conviction that much of the data from the military surveys are equally applicable or adaptable to non-military uses. This is particularly true of the vast body of anthropometric information which has been assembled, edited and standardized by the anthropology group of the Aerospace Medical Research Laboratory (AMRL) at Wright-Patterson Air Force Base into a facility known as the AMRL Anthropometric Data Bank, a resource which has grown over the last several years till it now comprises a uniquely comprehensive source of both military and civilian body size data.[2]

Although Clauser and McConville concede that certain gaps in data may exist for children and those older than 45, they do not view this as a serious obstacle:

> There are obviously other segments of the population not represented adequately in the data bank and there are undoubtedly data that are required by designers that have not yet been collected. When significant gaps in samples or anthropometry are identified, they can, in all likelihood, be filled by conducting relatively inexpensive studies of less than 500 carefully chosen subjects (Churchill and McConville, 1976).
>
> Despite the gaps, we believe that the AMRL Anthropometric Data Bank is a uniquely comprehensive and functional anthropometric data base from which a great variety of needed information can be readily obtained in usable form by commercial designers and engineers." (We want to add architects and interior designers to the users of these data.)

The major area of weakness, they advised, "remains at the point of contact between the various users and the anthropologists who are familiar with the existing data."[3]

As a profession we must generate the initiatives necessary to ensure proper contact. Above all, we must define and communicate our needs if we are to intelligently utilize anthropometric data to establish the proper relationship between human dimension and interior space. And utilize these data we must, if we are to improve the quality, comfort, and safety of our interior environments.

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E APPENDIX

NOTES

INTRODUCTION

1. Morris Hicky Morgan, *Vitruvius: The Ten Books on Architecture* (New York: Dover Publications, Inc., 1960), pp. 72-73.

2. Elvind Lorenzen, *Technical Studies in Ancient Metrology,* (Copenhagen: Nyt Nordisk Forlag Arnold Busk, 1966), p. 23.

3. Pierre Senghers and Jacques Charpier, *The Art of Painting* (New York: Hawthorne Books, Inc., 1964), p. 65.

4. Ibid., p. 95.

5. Harold Osborne, *The Oxford Companion to Art* (Oxford: Oxford University Press, 1920), p. 488.

6. Ibid.

7. Ibid.

8. Albert Damon, Howard W. Stoudt, and Ross A. McFarland, *The Human Body in Equipment Design* (Cambridge, Mass.: Harvard University Press, 1971), p. 2.

9. W. T. Singleton, *Introduction to Ergonomics* (Geneva: World Health Organization, 1972), p. 9.

10. Etienne Grandjean, *Ergonomics of the Home* (London: Halsted Press Division; New York: John Wiley & Sons, Inc., 1973), p. 106.

1. ANTHROPOMETRIC THEORY

1. Alphonse Chapanis, ed., *Ethnic Variables in Human Factors Engineering* (Baltimore and London: The Johns Hopkins University Press, 1975), p. 13.

2. C.B. Davenport and A.G. Love, *Army Anthropology* (Washington, D.C.: U.S. Government Printing Office, 1921)..

3. J.A. Roebuck, Jr., K.H.E. Kroemer, W.G. Thomson, *Engineering Anthropometry Methods* (New York: John Wiley & Sons, 1975), p. 5.

4. National Center for Health Statistics, *Weight, Height, and Selected Body Dimensions of Adults, United States 1960-1962,* PHS Pub. no. 1000, Series 11, no. 8 Public Health Service (Washington, D.C.: U.S. Government Printing Office, June 1965).

5. National Aeronautics and Space Administration, *Anthropometric Source Book,* 3 vols., Scientific and Technical Information Office, NASA Reference Pub. 1024, July 1978.

6. Ibid.

7. Albert Damon et al., *The Human Body in Equipment Design* (Cambridge, Mass.: Harvard University Press, 1971), p. 45.

8. J.A. Roebuck, Jr., et al., *Engineering Anthropometry Methods* (New York: John Wiley & Sons, 1975), p. 132.

9. National Aeronautics and Space Administration, *Anthropometry for Designers,* vol. 1, *Anthropometric Source Book,* NASA Reference Pub. 1024, Scientific and Technical Information Office, July 1978, p. IX-14.

10. Albert Damon et al., *The Human Body in Equipment Design,* p. 11.

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2. APPLICATION OF ANTHROPOMETRIC DATA

1. Dr. H.T.E. Hertzberg, "'Average' Man Is a Fiction: Range of Sizes Is Key to Efficient Work Places," *Contract,* September 1970, pp. 86-89.

2. Edward T. Hall, *The Hidden Dimension* (New York: Anchor Books, 1969), pp. 113-129.

3. M.J. Horowitz, D.F. Duff, and L.D. Stratton, "Body Buffer Zone: Exploration of Personal Space," *Archives of General Psychiatry 2* (1964), pp. 651-656.

4. John J. Fruin, PhD., *Pedestrian Planning and Design* (New York: Metropolitan Association of Urban Designers and Environmental Planners, Inc., 1971), pp. 64-69.

5. Harold M. Proshanskey, William H. Ittelson, and Leanne G. Rivlin, *Environmental Psychology: People and Their Physical Settings* (New York: Holt, Rinehart and Winston, 1976), pp. 161-162.

6. Archie Kaplan, "Designing for Man in Motion," *AIA Journal,* November 1971, pp. 42-44.

7. National Aeronautics and Space Administration, *Anthropometry for Designers,* vol. 1, *Anthropometric Source Book,* NASA Reference Pub. 1024, Scientific and Technical Information Office, July 1978, p. I-10.

8. Albert Damon et al., *The Human Body in Equipment Design* (Cambridge, Mass.: Harvard University Press, 1971), pp. 189, 193.

3. ELDERLY AND PHYSICALLY DISABLED PEOPLE

1. Albert Damon and Howard W. Stoudt, "The Functional Anthropometry of Old Men," *Human Factors,* October 1963, p. 488.

2. D.F. Roberts, "Functional Anthropometry of Elderly Women," *Ergonomics* 3, 1960, pp. 323-325.

3. Georges Selim, *Barrier Free Design* (Ann Arbor, Mich.: The Office of Disabled Student Services, University of Michigan, 1977), p. 2.

4. Herman L. Kamenetz, M.D., *The Wheelchair Book* (Springfield, Ill.: Charles C. Thomas, Publisher, 1969), p. 135.

4. ANTHROPOMETRICS OF SEATING

1. Julia Taynsford, *The Story of Furniture* (New York: Hamlyn Publishing Group, 1975), p. 10.

2. Peter Bradford and Barbara Prete, eds., *Chair: The Complete State of the Art* (New York: Thomas Y. Crowell, Publishers, 1978), p. 43.

3. E.R. Tichauer, *The Biomechanical Basis of Ergonomics: Anatomy Applied to the Design of Work Situations* (New York: John Wiley & Sons, 1978), p. 72.

4. Paul Branton, *The Comfort of Easy Chairs,* FIRA Technical Report no. 22 (Hertfordshire, England: Furniture Industry Research Association, 1966), p. 26.

5. E.R. Tichauer, *The Biomechanical Basis of Ergonomics,* p. 73.

6. Paul Branton, *The Comfort of Easy Chairs,* p. 61.

7. Ibid., p. 26.

8. Ibid.

9. Ibid. p. 29.

10. Ibid.

11. Ibid., p. 64.

12. Niels Diffrient, Alvin R. Tilley, and Joan C. Bardagjy, *Humanscale 1/2/3* (Cambridge, Mass.: The MIT Press, 1978), p. 20.

13. John Croney, *Anthropometrics for Designers* (New York: Van Nostrand Reinhold Company, 1971), p. 149.

14. Albert Damon et al., *The Human Body in Equipment Design* (Cambridge, Mass.: Harvard University Press, 1971), p. 315.

PART B

1. The terms in Table 9 have been excerpted from National Aeronautics and Space Administration, *Anthropometry for Designers,* vol. 1, *Anthropometric Source Book,* NASA Reference Pub. 1024, Scientific and Technical Information Office, July 1978, pp. VI-3 and VI-4.

EPILOGUE

1. National Aeronautics and Space Administration, *Anthropometry for Designers,* vol. 1, *Anthropometry Source Book,* NASA Reference Pub. 1024, Scientific and Technical Office, July 1978, p. 111.

2. Charles E. Clauser and John T. McConville, "The Aerospace Medical Research Laboratory's Anthropometric Data Bank: A Resource for Designers" (Paper delivered at the meeting of the American Psychological Association, San Francisco, August 1978), p. 3.

3. Ibid., p. 11.

GLOSSARY

Abduction: movement of a body segment away from the midline of the body or body part to which it is attached.

Adduction: movement of a body segment or segment combination toward the midline of the body or body part to which it is attached.

Ambulant: moving about, walking.

Ambulant disabled: physically disabled individual still capable of moving about but with difficulty and insecurity, using canes, walkers, and other aids.

Anthropometry: the science of dealing with measurement of the human body to determine differences in individuals, groups, etc.

Average: the numerical result obtained by dividing the sum of two or more quantities by the number of quantities; an arithmetical mean.

Ball and socket joint: joints such as the hip and shoulder that permit rotation as well as movement in all planes.

Biomechanics: the application of the principles and techniques of mechanics to the structure, functions, and capabilities of living organisms.

Body buffer zone: an area of personal space that appears to surround every individual.

Body linkage system: a concept used when describing body motion that views the body as having a system of links, which theoretically are pure straight line distances between centers of joint rotation.

Center of gravity: that point in a body or system around which its weight is evenly distributed or balanced and may be assumed to act.

Column dragrams: see *histogram.*

Dynamic dimension: see *functional dimension.*

Dysfunction: abnormal, impaired, or incomplete functioning, as of a body organ or part.

Ergonomics: the study of the problems of people in adjusting to their environment; the science that seeks to adapt work or working conditions to suit the worker.

Ethnicity: ethnic classification or affiliation.

Eversion: rotation of the foot, which involves lifting the lateral border to turn the sole or plantar surface outward.

Extension: straightening or increasing the angle between the parts of the body, generally defined as the return from flexion. When a joint is extended beyond the normal range of its movement, the movement becomes known as "hyperextension."

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Flexion: bending or decreasing the angle between the parts of the body.

Functional dimension: body dimensions taken with the body in various working positions; formerly referred to as "dynamic" dimensions.

Gait: manner of moving on foot; way of walking or running.

Goniometer: an instrument for measuring angles.

Hinge joint: joints permitting wide range of movement in only one direction.

Histogram: a graphic representation of a frequency or relative frequency distribution, consisting of vertical rectangles whose widths correspond to a definite range of frequencies and whose heights correspond to the number of frequencies occurring within the range.

Inversion: lifting the medial border of the foot to turn the sole inward.

Ischemia: a lack of blood supply in an organ or tissue.

Ischial tuberosity: the rounded portion of the bone on which the body rests when sitting.

Kinesiology: the science or study of human muscular movements.

Kyphosis: increased curvature of the thoracic spine.

Lateral rotation: turning away from the midline of the body.

Lordosis: curvature of the spine producing a hollow in the back.

Lumbar: designating or of the vertebrae, nerves, arteries, etc., in the part of the body just below the thoracic part.

Medial rotation: turning toward the midline of the body.

Median: the value in the middle range when a number of values are arranged in numerical order; the value located at a point where as many values fall below it as above it.

Metrication: the process of changing over to the metric system of weights and measures.

Metrology: the science of weights and measures.

Patella: kneecap.

Percentile: any of the values in a series when the distribution of the individuals in the series is divided into 100 groups of equal frequency.

Popliteal height: distance measured vertically from the floor to the underside of the portion of the thigh just behind the knee while the subject is seated with body erect.

Pronation: rotating the forearm so that the palm faces downward.

Secular change: human variation in body size, rate of growth, and development occurring from generation to generation over time.

Static dimension: See *structural dimension*.

Stature: vertical distance from the floor to the top of the head.

Structural dimension: dimensions which are taken with the body of the subject in fixed, standardized positions; formerly referred to as "static" dimensions.

Supination: rotating the forearm so that the palm faces upward.

Tabular: arranged in a table or tabulated scheme.

Taxonomy: the science of classification.

Torso: the trunk of the human body.

Visual angle: the angle subtended at the eye by the viewed object.

ANTHROPOMETRIC DATA/ SOURCES

PRIMARY SOURCES*

Aerospace Medical Research Laboratory
Wright-Patterson Air Force Base
Dayton, Ohio

Anthropology Research Project, Inc.
Yellow Springs, Ohio

Centre d'Anthropologie Appliquée
Université de Paris
Paris, France

Department of Human Anatomy
University of Newcastle
Newcastle-on-Tyne, England

Highway Safety Research Institute
University of Michigan
Ann Arbor, Michigan

U.S. Army Natick Laboratories
Natick, Massachusetts

SECONDARY SOURCES†

Aerospace Crew Equipment Laboratory
Naval Air Engineering Center
Philadelphia, Pennsylvania

Biotechnology Laboratory
University of California, Los Angeles
Los Angeles, California

Bureau Internationale du Travail
Geneva, Switzerland

Department of Ergonomics and Cybernetics
Loughborough College of Technology
Leigestershire, England

Furniture Institute Research Association
Stevenage, Hertfordshire, England

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

Institute of Engineering Production
University of Birmingham
Birmingham, England

Institute for Psychological Research
Tufts University
Medford, Massachusetts

Royal Air Force Institute of Aviation Medicine
Farnsborough, Hampshire, England

U.S. Naval Training Devices Center
Orlando, Florida

Unit for Research on Human Performance in Industry
Welsh College of Advanced Technology
Cardiff, Wales

*Anthropometric laboratories specializing in research as well as gathering a library of data.

†Repositories of anthropometric data (actual anthropometric services may not necessarily be available).

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SELECTED BIBLIOGRAPHY

Branton, Paul. "The Comfort of Easy Chairs." FIRA Technology Report no. 22. Stevenage, Hertfordshire, England: Furniture Industry Research Association, 1966.

Callender, John. *Time-Saver Standards for Architectural Design Data.* 5th ed. New York: McGraw-Hill Book Company, 1974.

Chapanis, Alphonse. *Ethnic Variables in Human Factors Engineering.* Baltimore: Johns Hopkins University Press, 1975.

Croney, John. *Anthropometrics for Designers.* London: B.T. Batsford, Ltd.; New York: Van Nostrand Reinhold Company, 1971.

Bradford, Peter, and Prete, Barbara, eds. *Chair.* New York: Thomas Y. Crowell, Publishers, 1978.

Damon, Albert; Stoudt, Howard W.; and McFarland, Ross A. *The Human Body in Equipment Design.* Cambridge, Mass.: Harvard University Press, 1966.

DeChiara, J., and Callender, J. *Time-Saver Standards for Building Types.* New York: McGraw-Hill Book Company, 1973.

Diffrient, Niels; Tilley, Alvin; and Bardagjy, Joan. *Humanscale 1/2/3.* Cambridge, Mass.: The MIT Press, 1978.

Dreyfuss, Henry. *The Measure of Man: Human Factors in Design.* New York: Whitney Library of Design, 1966.

Farris, Edmond J. *Art Students' Anatomy.* New York: Dover Publications, 1961.

Fogel, L.J. *Biotechnology: Concepts and Applications.* Englewood Cliffs, N.J.: Prentice-Hall, 1963.

Fruin, John, PhD. *Pedestrian Planning and Design.* New York: Metropolitan Association of Urban Designers and Environmental Planners, Inc., 1971.

Gerhardt, John, M.D., and Russe, Otto A., M.D. *International SFTR Method of Measuring and Recording Joint Motion.* Bern, Switzerland: Hans Huber Publishers, 1975.

Grandjean, Etienne. *Ergonomics of the Home.* New York: Halstead Press, Division of John Wiley & Sons, 1973.

Gray, Henry. *Gray's Anatomy.* New York: Bounty Books, n.d.

Hall, E.T. *The Hidden Dimension.* Garden City, N.Y.: Doubleday & Company, Inc., 1966.

———. *The Silent Language.* New York: Fawcett World Library, 1959.

Harkness, Sarah P., and Groom, James N., Jr. *Building without Barriers for the Disabled.* New York: Whitney Library of Design, 1976.

Human Factors Engineering AFSC Design Handbook. Department of the Air Force, Hq. Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, 1977.

Kamenetz, Herman L., M.D. *The Wheelchair Book.* Springfield, Ill.: Charles C. Thomas Publisher, 1969.

Kaplan, Archie. "Designing for Man in Motion." *AIA Journal,* November 1971.

Lockhart, R.D. *Living Anatomy: A Photographic Atlas of Muscles in Action.* 7th ed. London: Faber & Faber, 1974.

Muybridge, Eadweard. *The Human Figure in Motion.* New York: Dover Publications, 1955.

National Aeronautics and Space Administration. *Anthropometric Source Book.* 3 vols. NASA Reference Publication 1024, Scientific and Technical Information Office, July 1978.

Pile, John F. *Modern Furniture.* New York: John Wiley & Sons, 1979.

Proshansky, Harold; Ittelson, William; and Rivlin, Leanne. *Environmental Psychology: People and Their Physical Settings.* New York: Holt, Rinehart and Winston, 1976.

Ramsey, Charles G., and Sleeper, Harold R. *Architectural Graphic Standards.* 6th ed. New York: John Wiley & Sons, 1970.

Roebuck, J.A.; Kroemer, K.H.E.; and Thomson, W.G. *Engineering Anthropometry Methods.* New York: John Wiley & Sons, 1975.

Singleton, W.T. *Introduction to Ergonomics.* Geneva, Switzerland: World Health Organization, 1962.

Sommer, Robert. *Personal Space: The Behavioral Basis for Design.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969.

Steidl, Rose E., and Bratton, Esther Crew. *Work in the Home.* New York: John Wiley & Sons, 1968.

Tichauer, E.R. *The Biomechanical Basis of Ergonomics: Anatomy Applied to the Design of Work Situations.* New York: John Wiley & Sons, 1978.

Van Cott, Harold P., PhD., and Kinkade, Robert G., PhD. *Human Engineering Guide to Equipment Design.* Rev. ed. Washington, D.C.: American Institutes for Research, 1972.

Woodson, W.E., and Donald W. Conover. *Human Engineering Guide for Equipment Designers.* 2d ed. Berkeley and Los Angeles: University of California Press, 1964.

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INDEX

Italicized page numbers indicate illustrations.

Abduction, 45, 114
Adduction, 45, 114
Adjustability, 38, 63, 76
Age, 26, 37, 63; as category in study of adults, 47–49, 83, 85–99; as category in study of children, 106–110; as factor in body size, 19, 23, *25,* 36; as factor in range of joint motion, 45
Alexander, M., 103
Ambulant disabled people, 55
American National Standards Institute (ANSI), 51, 53
Anthropometer, 28
Anthropometric instruments, 27, *28, 29,* 43
Anthropometric recording form, 31, *32*
Anthropometric Source Book (NASA), 27, 34, 74, 101
Anthropometrie (Quetlet), 23
Anthropometry, 23–26; comparative racial, 23; defined, 23; functional, in the elderly, 47–49
Anthropometry of U.S. Infants and Children (Snyder, Spencer, Owings, & Schneider), 105
The Anthropometry of Working Positions (Hertzberg, Emanuel, & Alexander), 103
Architectural and Transportation Barriers Compliance Board, 54
Armrest, 59, 60, 65–67, 78
Audiovisual spaces, 283–297
Average man, fallacy of the, 25, 34, 37, 38, 50

Backrest, 59, 60, 65, 66, 80
Bars, 215–218
Basics, of audiovisual spaces, 285–288
Bathrooms, 163–168
Body buffer zone, 40, *40,* 41, *42*
Body dimensions, children's, 28, 105, 106. *See also* Body Size
Body linkage system, 43, *44*
Body size, 15, 17–19, 23, 25, 27, 29, 31, 45, 47, 57, 63, 83; of chairbound people, 52, 53; variations in, 34, 36–38, 101. *See also* Body dimensions and Structural body dimensions
Bonomi, J., 17, *17*
Branton, 57, 67; quoted, 59
Breadth. *See* individual body parts
British Navy, 26
Buffon, 23
Buttock-knee length, 31, *35,* 80, 83, 94, 107, 109
Buttock-leg length, 80
Buttock-popliteal length, 31, 65, 79, 83, 93, 107, 108
Buttock-toe length, 80

Canes, 54, 55
Cennini, Cennino, 15, 17
Center of gravity, 59, *59*
Chairbound people, 50, *52, 53,* 55
Circulation zone, 40, 41
Clearance, 38, *38,* 40, 43, 50, *51,* 54, 59, 66, 75–80, 82
Clothing, 63, 76, 77, 82
Column diagram, 33
Conference rooms, 191–194
Conover, Donald W., 74, 97, 99
Cooking spaces, 157–162
Crinionmento, 27
Croney, 67
Crutches, *54,* 55
Cushioning, 63, 66, 67, 76–79, 81

Damon, Dr. Albert, 27, 47, 67, 74, 83, 84, 103
Daniels, 97, 99
Data: appropriateness of, 37, 57, 71; presentation of, 31, 33; restraints of, 45; sources of, 26, 27; type of 27, 31
da Vinci, Leonardo, *16,* 17
Dental treatment rooms, 237–240

Diffrient, Neils, quoted, 57
Dining spaces, 137–146, 223–230
Dionysius, 15
Displays for group viewing, 293–297
Distance zones, *39*, 40, *41*
Distribution: Gaussian, 33; pattern of, 31, 33, *35*
Divina Proportione (Paccoli), 17

Eating and drinking spaces, 213–230
Elbow/forearm joint motion, 113, 114, 116
Elbow height, 75
Elbow rest height, 66, 78, 83, 89
Elbow seat height, 66
Elbow-to-elbow breadth, 31, *31*, 77, 78, 83, 95, 107, 110
Elderly people, 47, *48*, 49. *See also* Age
Emanuel, I., 103
Ergofit, 19
Ergonomics, defined, 18
Ethnic variabilities, 19, 23, *24*, 25, 36, 37
Euclid, 18; quoted, 17
Eversion, 114
Exercise areas, 249–254
Extension, 45, 114
Eye height, 75, 76

Fashion Institute of Technology, 29
Fingers joint motion, 113, 117
First International Symposium on "Natural and Cultural Variables in Human Factors Engineering" (1972), 36
Flexion, 45, 75, 114
Flight distance, 40
Food counters, 219–222
Food stores, 205–208
Foot joint motion, 113, 114, 119
Forward arm reach, 82
Frequency: histogram, 33, *33;* polygon, 33, *33;* table, 31, 33, *33*,
Fruin, Dr. John J., 40, *41*
Functional ("dynamic") body dimension, 27, 45, 47–49, 105; adult male and female, 99, 100, 107

General office, 175–186
Gibson, John, 17, *17*
Golden Section, 17, 18, *18*
Goniometer, 43

Hair styling, 209–212
Hall, quoted, 40
Hamill, Peter V. V., 105
Hand length, 34
Harvard School of Public Health, 27, 83
Head, face, hand, and foot dimensions, 107, 111, 112
Headrest, 59
Health care spaces, 231–246
Height, *25*, 26, 31, 33, 34, 42, 47. *See also* body part and Stature
Hertzberg, Dr. H.T.E., 37, 97, 99, 103; quoted, 38
Hidden dimensions, 38, 40, 82
Hip breadth, 31, 78, 96, 107, 110
Horizontal circulation spaces, 265–270
Horowitz, 40
Hospital rooms, 241–246
The Human Body in Equipment Design (Damon, Stoudt, & McFarland), 74, 103, 104
"Human Body Size in Military Aircraft and Personnel Equipment," (Randall et al., 1946), 27
Human dimension, 18, 19, 25, 27, 28, 30, 31, 33, 34, 36–38, 50, 66; of greatest use to interior designer, 30, 31; normal curve of, 33
Human engineering, 18, 19, 31
Human Engineering Guide for Equipment Designers (Woodson & Conover), 74, 97, 99
Human factors engineering, 36; defined, 18
Human Factors Engineering (AFSC), 103, 104, 111, 113
Hyperextension, 114

Interpupillary diameter, 31
Inversion, 114
Ischemia, 59

Joint motion: range of, 43, *43*, 45, 47, 113, 115–119; terminology of, 114
Joints, types of, 43, 45

Kamentz, Dr. Herman L., quoted, 50, 55
Kaplan, quoted, 40
Knee height, 31, 33, 35, 79, 83, 91, 107
Knee joint motion, 113, 118

Lateral rotation, 45, 114
Le Corbusier, 17, *17*, 18
Leisure and recreational spaces, 247–262
Lemeshow, Stanley, 105
Length. *See* individual body part
Linne, 23
Living spaces, 131–136
Lumbar region, 65, *65*, 66

McFarland, Dr. Ross, 27, 74, 83, 84, 103
Malina, Robert M., 105
Man-machine interface, 19
Maximum body breadth, 82
Maximum body depth, 82
Medial rotation, 45, 114
Medical treatment rooms, 233–236
Menton-supramentale, 27
Mercantile spaces, 195–212
Metrological analysis, 73–82
Michigan Center for a Barrier-Free Environment, 50
Military-industrial research, 18, 19, 23, 26, 27, 36, 40, 47, 71, 113
Miscellaneous structural body dimension, adult male and female, 97–99
Modular No. 1, 17, *17*
Motion, people in, 40, 42, 43. *See also* by joint

National Aeronautics and Space Administration (NASA), 27, 34, 42, 74, 97, 99
National Center for Health Statistics, 28, 32, 36
National Health Examination Survey: Selected Body Measurements of Children 6-11 Years, 1963-1965, 105
"National Health Survey 1962: Weight, Height and Selected Body Dimensions of Adults, United States 1960-1962," 83–96
Neck joint motion, 113, 115
North Atlantic Treaty Organization, 36
No-touch zone, 40, *41*

Occupational factors in body size and measurement, 23, 36, 37
Office spaces, 169–194

Paccoli, Luca, quoted, 17
Percentiles, *35*, 38, 53, 66, 83; defined, 34; fifth or ninety-fifth, 50, 63, 65, 73, 97, 99, 101, 103, 111; selected, 83, 85–96, 102, 104, 106–110, 112
Percentile selection, 75–82
Personal comfort zone, 40, 41
Personal distance, 40, *40*, 41
Physical conditions as factor in data gathering, 23, 25, 26
Physically disabled people, 50, *50*
Popliteal height, 31, 63, 78, 79, 83, 92, 107, 108
Private office, 171–174
Projected 1985 body dimensions, adult male and female, 101, 102, 107
Pronation, 45, 114
Proportion, 15, 17, 18
Public bathrooms, 275–278
Public convenience facilities, 279–282
Public spaces, 263–282

Quetlet, 23

Randall, Damon, Benton, and Patt, 27
Reach, 38, 43, 50, 52, 53, 99; arm, *35*, 38, 42, *42*, 50, 55, 78, 82; average, 50; functional, 43, *43*, 100; overhead, 47, 81

WHITNEY LIBRARY OF DESIGN

Reception spaces, 187–190
Residential spaces, 131–168
Retail spaces, 197–204
Roberts, D.F., 25, 47
Roberts, Jean, 27, 83, 84
The Royal Air Force, 26

Seat: breadth, 83; depth, 60, 63–65, 79; height, 60, 62, 63, 65, 75, 76, 78, 79; width, 60, 65, 77, 78
Seating, 19, 40, 41, 57, 59, 60, 63, 65, 66, 67; anthropometrics of, 57–68; basic design reference standards for, 125–130; considerations for, 60; dimensions for, *60;* dynamics of, 57–60
Secular change, 36, 101
Seeing-eye dogs, *54,* 55
Sex: as factor in body size, 23, 25, 26, 36, *36,* 37, 47, 53, 82, 85–96, 102, 106–110; as factor in range of joint motion, 45
Shoulder: breadth, *41,* 76, 77; height, *35,* 77; joint motion, 113, 116
Side arm reach, 81
Sight lines, 75, 76
Sitting, 42, 43, 57, 59, 60
Sitting height, 31, 34; erect, 76, 83, 87, 107; normal, 76, 83, 88
Sleeping spaces, 149–156
Snyder, Spencer, Owings, and Schneider, 105
Society of Automotive Engineers, 105
Socioeconomic factors, 25, 26, 36, 63
Sommer, 40, *41*
Space: perception of, 40, *41;* psychological aspects of, 45
Spatial envelope, 42, *42*
Spine joint motion, 113, 115
Sports and games, 255–258
Stability in seating, 59, 60, *62,* 63, 67
Standing height, 33, 38
Static measurements, 99. *See also* Structural body dimensions
Statistical methodology, 26, 37
Stature: adult, 18, 23, 24, 25, *25,* 26, 34–37, *36,* 47, 75, 83, 86; children, 105–107. *See also* Height
Stoudt, Dr. Howard W., 27, 47, 74, 83, 84, 103
Structural body dimensions, adult male and female, 83–86; miscellaneous adult male and female, 97–99; weight and, of children, 105–110
Structural ("static") dimensions, 27
Supination, 45, 114

Thigh clearance height, 31, 79, 83, 90, 107, 109
Tichauer, quoted, 57
Touch zone, 40, *41*
Tuberosity, ischial, 57, *58,* 59, 67

U.S. Air Force (USAF), 26, 101; Systems Command (AFSC), 103, 111, 113; Women's Survey (1968), 101
U.S. Department of Health, Education, and Welfare (HEW), 27, 50, 101
U.S. Department of Housing and Urban Development, 54
U.S. Military Study, 1919, 26
U.S. National Health Survey (Damon et al.), 27, 47, 71, 101; quoted, 31
U.S. Navy Flying Personnel, 101
U.S. Public Health Service, 47, 83; Division of Health Examination Statistics, 27, 83
University of Michigan, 105

Variability and reliability in body size measures, 36
Vertical circulation spaces, 271–274
Vertical reach, 81
Visibility, 75, 76, 77
Vitruvian Man (Gibson & Bonomi), 17, *17*
Vitruvius, 17, 18; quoted, 15

Walkers, *54,* 55
Weight: adult, 19, *25,* 26, 31, *36,* 37, 57, 59, 67, 83, 85; children, 105–107
Wheelchair, 50, *51*
White, 23
Woodson, Wesley, 74, 97, 99
Work and craft centers, 259–262
Working positions, 19, 27, 75–79; adult male, 103, 104
Wrist joint motion, 44, 45, 113, 117

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