THE MEASURE OF MAN AND WOMAN

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HUMAN FACTORS IN DESIGN

ALVIN R. TILLEY

HENRY DREYFUSS ASSOCIATES

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PREFACE

Henry Dreyfuss Associates, an industrial design consultancy, has led the way in applying human-factors data to product development for more than 60 years. Now, in a comprehensive revamping of the company's earlier landmark book, *The Measure of Man*, published in 1960, this volume represents the culmination of their efforts since then to document and publish up-to-date information for use by designers, architects, and engineers. *The Measure of Man and Woman* assembles the most vital data currently available to assist designers in creating products and environments to better accommodate human needs. We hope that the application of this data will help people everywhere in their quest for safety, comfort, and satisfaction.

Recent endeavors have included compiling and integrating statistical information pertaining to the differently abled, to pregnant women, and to children. Prior to this volume, no such information regarding these groups existed in a complete and usable format.

The key figure in this development, and in the creation of *The Measure of Man and Woman*, has been Alvin R. Tilley, one of the world's foremost experts in applied anthropometry. By combining data from numerous surveys, Tilley created a set of reference tools that have become indispensible to design professionals. As co-author of *The Measure of Man; Humanscale 1/2/3*, 1974; and *Humanscale 4/5/6* and *7/8/9*, 1981, he prepared detailed and easy-to-use diagrams of human dimensions presented in the context of living. He has done so again in this volume. Whether male or female, young or old, large or small, people have been studied in their various environments in numerous postures and meticulously rendered for the pages that follow. [*Editor's note: Alvin R. Tilley died in July 1993, before publication of this book.*]

Other Dreyfuss staff members who contributed significantly to the book are Brad Agry, John McFarlane, Jim Ryan, Rebecca Simms, and William Wenger.

INTRODUCTION

Designing for people is not new; it is as old as humankind. In the last 60 years, however, the field of *human factors*—the study of human capabilities and limitations—has become a science that is ever-expanding through the labors of many talented and devoted people around the globe. As science advances in many fields, the task of accommodating all human beings with comfort and safety becomes increasingly complex. The designer must keep informed by reading numerous books, journals, magazines, and papers and by consulting with specialists.

To a great extent, people's needs for comfort and safety are not being met, and despite all the available data, lapses in good design are frequent. There are still many poorly designed objects causing accidents. Seats in buses, trains, and homes are often uncomfortable. Many computer operators suffer back and wrist strains. There is much work to be done to humanize this world.

Design considerations now encompass more people, products, and environments. Moreover, they have become a global matter, and designers today need to take into account physical differences among international populations—but without compromising the needs of the statistically defined "average" person. With increased sensitivity, designs can become nearly universal; scarcely any user group will be excluded from having its needs met.

The Measure of Man and Woman is a contribution to this effort. The book is based on a large quantity of data accumulated over more than 40 years by Henry Dreyfuss Associates, which found the collection invaluable in making product designs more successful. The data in this volume embraces 98% of the adult population, and new information is provided regarding products and environments for infants, toddlers, youths, the elderly, and the differently abled. Work stations, displays, and controls used in electronic equipment and computers have also been carefully studied and included.

Continuing to integrate research findings from anthropometrics and ergonomics, as first initiated by Alvin Tilley and Henry Dreyfuss, we have broadened the human-factors view to include cognition—the users' thought processes—in the design equation. Products have become operationally more complex, and a product's physical form often envelops numerous hidden possibilities that await the user's beck and call. As with the microprocessor and the computer, a product's behavior may vary depending on the user's input and the if-then conditions programmed into the product. Through the application of cognitive ergonomics to design, products can become easier to use.

We ask that our technologist friends from the various specialties within the field of human factors understand that our brush is wide in order to support the widest audience. Both the text and the drawings in this book attempt to make data from a range of scientific studies readily available to designers who might otherwise find such sources esoteric or inaccessible. They are intended as a clear and effective means of displaying complex information on sizes, limitations, and conditions. We trust that our readers will find our presentation format quick and easy to use and, additionally, we hope that they will absorb much of the current thinking in human factors into their own design conceptions.

HUMAN FACTORS: A BRIEF HISTORY

The term *human factors* encompasses both physiology and psychology and covers most factors affecting human performance of tasks using tools or in man-made environments. For example, visual acuity, hearing, tactile sense, temperature, and humidity are quite clearly factors that affect performance, but the degree of a person's training, his or her diet, and other factors are considered as well. Human factors is the sphere of accumulated data.

The Measure of Man and Woman is an outgrowth of the human factors field, and it should thus prove useful to engineers, architects, industrial designers, interior designers, craftspeople, artists, and students.

Accommodation began with the creation of tools in prehistoric times. When bones of hominids that dated back to more than 1 million years ago were uncovered in Kenya, Africa, bone and stone tools were found. Thumb tools that were probably used for scraping skins and hand tools for heavier work were, by then, already extensions of the hand.

Bows and arrows extended the hand even further. The bow was designed for the strength of the hunter or warrior. The arrow length was usually designed for the maximum reach in the drawing of the bow. The age of these tools is not known for certain, because the materials of which they were made perished easily.

Nine-thousand-year-old obsidian mirrors were unearthed at Catal Hüyük, Turkey. The sharp, chipped edges were covered by a plaster-like material to protect the user or to provide comfort. Four thousand years ago, war chariots were used in Mohenjo-Daro, in western Pakistan. They were designed to accommodate the driver and an archer side by side. The space necessary determined the spacing of the wheels—a spacing almost identical to the standard wagon track and early railroad gauge.

Measuring many items by the cubit (elbow to the tip of the middle finger), the ancient Egyptians developed chairs, ventilated beds, fast chariots, and seaworthy boats. Similarly, in the Middle Ages, measurements were made by body parts: a seat height would equal five fists, or a half-leg length.

The machine age arrived less than 200 years ago, and 100 years ago, time-and-motion engineering emerged. During the early modern period, the machine assumed priority in design considerations, and the operator came last. For instance, early aircraft were designed only for operators of a certain size. When operators of this size became scarce, the concept of *human engineering* began by analyzing the workspace to accept a variable population.

Human engineering (a term used by the U.S. Army, whereas *human factors* is used by other branches of the military) is the connection between the human and the mechanical or the extension of the former by the latter. Before World War II, engineers and architects had some physical guidelines (space required to climb ladders and stairs, space for maintenance access, space for dining); these were usually based on the average man. Measurements were taken by the U.S. Department of Agriculture, with the WPA, and garment pattern sizes were consulted, but most of these measurements were not useful for human engineering.

World War II required new and complex war machines, and the concept that machines, not personnel, win wars gave way to efficient man-machine relationships. Before long, many scientific disciplines were being consulted—psychology, engineering, anthropology, and physiology. The Department of Defense issued human engineering standards for the design of military equipment for the Army and human-factors information for the Air Force and the Navy; this included data pertaining to undersea craft as well. This work was based on 90% of the adult males acceptable for certain segments of military service. Military equipment designed for this segment could be kept small with a low silhouette and smaller profile for greater combat safety.

A comparison of measurements of stature taken during the various American wars reveals that men were growing at the rate of 0.4" (1 cm) every decade.

By the 1960s, a systematic gathering of data was ongoing, and the U.S. Department of Health, Education, and Welfare published "Weight, Height, and Selected Body Dimensions of Adults." This civilian data was not as comprehensive as the military data, however. Then, in the '70s, the Society of Automotive Engineers made a very useful survey of children, from two-month-old infants to eighteen-year-old youths.

In the '80s, the elderly were measured when it became apparent that they were becoming a large segment of the population. Accordingly, in the '90s, the Americans with Disabilities Act (ADA) became law and prohibited discrimination on the basis of disability. The act sets down rules of accessibility and protection for wheelchair occupants, for the blind and visually impaired, and for the deaf and hearing impaired.

Today's designers must be aware of the whole population. International air travel and the design of industrial and agricultural equipment all over the world have created a need for anthropometrical study of the world population.

Cognitive science now also informs the field of design; it studies the mind: awareness, decision making, difficulty, and related issues.

The Human Factors Society was founded in 1956 in the United States, six years following the founding, in Great Britain, of the Ergonomic Research Society. The term *ergonomic*, which is used more and more as the total application of all human factors, comes from the Greek *ergos*, meaning work, and *nomos*, meaning natural laws. Originally synonymous with *human factors*, which encompasses the similar expressions *applied human factors, human factor engineering, human engineering*, and *applied ergonomics, ergonomics* is becoming an almost universal term.

ANTHROPOMETRY, OR THE MEASURE OF MAN, WOMAN, AND CHILD

MEASUREMENT SYSTEMS

In gathering data on the size of the body and its components, movement limitations, and strength—all of which are required to establish human-machine relationships and other design requirements—numerous measurement devices are employed. These are often similar to those used by engineers to measure machines or by sculptors in their work.

- The anthropometer is similar to a height gauge, with direct-reading scales up and down and in and out in several sizes. The largest is used to measure such things as stature and waist height. A middle size version is used to measure sitting height, knee height, buttock to knee, and similar intervals. A smaller size device is used to measure facial features from a backboard and a headboard.
- A direct-reading sliding caliper is used to measure body width and depth. A small size is used to measure parts of the hand and the width of the ears and mouth, and to determine biceps and arm widths.
- Direct-reading spreading calipers are used to measure head widths and depths.
- Special block rulers measure ankle heights.
- Special foot-measuring boxes include scales.
- Flexible tape scales are used to measure body circumferences and other dimensions used in clothing design.
- Templates measure finger diameters.
- Weight scales measure body weight.
- Force scales measure strength.
- Protractors measure angles.

With so many measuring tools involved, anthropometry becomes time-consuming and expensive. The most complete and reliable information has been prepared by the military forces, while civilian data is not complete. More recently, measuring techniques have improved with the addition of digitizers, including optical scanners.

The Society of Automotive Engineers, Inc., published a book entitled *Anthropometry of Infants, Children and Youths to Age 18 for Product Safety Design* (1977). In this survey, measuring tools were modified to read directly into a computer from a position signal, activated by a cable rotating a potentiometer. Modified calipers and anthropometers were equipped with sets of pointers and extensions to reduce the number of tools. Body circumferences were measured by a rolled tape that recorded the distance at the push of a button.

Occasionally, an odd dimension was required with a standard measuring device; in this case, it was entered by the anthropometrist, who keyed the data into the computer. Important measurements were taken on all subjects. Minor measurements were random, to reduce time and cost.

Computer-aided anthropometry will eventually be perfected to give both static and animated figures on a screen.

SAMPLING THE POPULATION

Large countries—the United States, for example—need large samplings, i.e., 2000 to 4000 each for men and women. A larger number of subjects results in greater accuracy. Measurements obtained throughout the country can include the following data:

- Birthplace
- Age
- Handedness (right, left, or ambidextrous)
- Color vision
- Ancestry
- Age of women at menarche (first menstruation)
- Demographic and economic factors

THE MEASUREMENTS

There are several standard measuring setups:

- The subject stands with his or her back against a backboard to insure an erect body posture; the body weight is distributed equally, and the arms, fingers, and legs are fully straightened. The body is straight but not rigid. A horizontal headboard is useful for some facial measurements.
- The subject sits erect on a flat horizontal surface, and the height is adjusted with the shank vertical and close to—but without pressure on—the popliteal area. Body weight is distributed equally, and the torso is held erect but not rigid.
- In both setups the head is held vertically and measurement is determined by making the Frankfort line horizontal. This is done by lining up the earhole and the lower part of the eye orbit (eye socket).
- The subject is placed in the supine position on a flat horizontal plane. This measuring posture is used for infants up to 24 months who cannot stand erect. In this case, stature (standing height) measurement is superseded by a length measurement from crown to sole.

Measurements between bony protuberances and end points (for example, from elbow to the dactylion) are preferred. Flesh measurements may not be as accurate. Stature and other heights are vertical dimensions; width (breadth) is measured horizontally. Depth measurements are made from front to back horizontally. Distance, a measure between two landmarks, can be in any direction. Circumference of body or body components is usually taken horizontally on the standing subject. Other measurements are taken for the clothing industry.

PERCENTILES

Body dimensions can be plotted on a graph with the measurements on the horizontal x axis increasing toward the right from the zero point. The frequency of occurrences is plotted on the vertical y axis, increasing toward the top from the zero point. A smooth curve averaging a particular height dimension will appear bell-shaped (Gaussian or normal distribution curve). In this case, the mean, median, and mode coincide. The *mean* is the arithmetical average of values, the *median* is the middle number of a series, and the *mode* is the most commonly occurring value and the highest point on the curve. If weight or flesh measurements (for example, hip width, buttock depth, or abdominal depth) are plotted, the resulting curve is not symmetrical—the peak of the curve is off-center. This curve is referred to as a *skew curve*. In this case, the mean, median, and mode do not coincide. Data from one dimension do not necessarily correlate with that of other dimensions. For instance, a small woman may have a small or large hip width or buttock depth, and so on. This information is worth keeping in mind when designing for an "average" person.

It is not customary to design for everyone. The few at either end of the normal curve may be so extreme that an encompassing design could become too large or expensive to produce. The military chose to exclude 5% at the small end and 5% at the large end, thus accommodating 90% of the measured population in the Military Standards. The 5% value is called the 5 percentile, and the 95% value is called the 95 percentile. Any other percentile values may be chosen by using the following table for estimating the height of various percentiles.

Table for Estimated Percentiles

Percentile	% Included
99.9 = Mean + (3 x SD)	99.8
99.5 = Mean + (2.576 x SD)	99
99 = Mean + (2.326 x SD)	98
97.5 = Mean + (1.95 x SD)	95
97 = Mean + (1.88 x SD)	94
95 = Mean + (1.65 x SD)	90
90 = Mean + (1.28 x SD)	80
85 = Mean + (1.04 x SD)	70
80 = Mean + (0.84 x SD)	60
75 = Mean + (0.67 x SD)	50
50 = Mean	
25 = Mean - (0.67 x SD)	50
20 = Mean - (0.84 x SD)	60
15 = Mean - (1.04 x SD)	70
10 = Mean - (1.28 x SD)	80
5 = Mean - (1.65 x SD)	90
3 = Mean - (1.88 x SD)	94
2.5 = Mean - (1.95 x SD)	95
1 = Mean - (2.326 x SD)	98
0.5 = Mean - (2.576 x SD)	99
0.1 = Mean - (3 x SD)	99.8

SD = Standard Deviation, which can be found by the formula:

$$SD = \sqrt{\frac{\Sigma (d)^2}{N}}$$

where Σ = summation,
d = difference between one person's measurement and the arithmetic mean of that measurement
N = number of people in the survey.

There is a particular Standard Deviation for every measurement and every sample.

We have chosen to accommodate 98% of the U.S. population, which lies between the 99 percentile and the 1 percentile, for product designs for civilians. Any lower percent excludes a good number of tall operators. A case in point: Canadian and U.S. farmers who operate agricultural equipment are taller and heavier than the general population (Casey, 1989). Their 95 percentile stature is 75.6" (1920 cm), which coincides with our 99 percentile male data and therefore will be included.

If one prefers a different percentile, the standard deviation can be calculated from data on the anthropometric diagrams in this book.

For example:

2.326 SD = 99 percentile stature - mean stature

$$SD = \frac{6.5"}{2.326} = 2.8" \text{ (71 mm)}$$

or

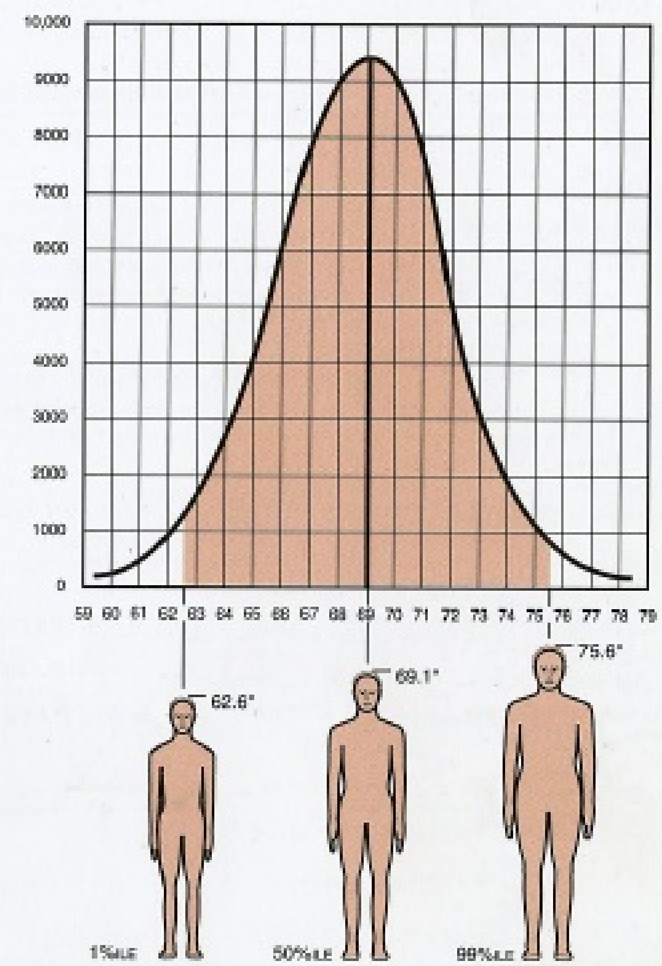
2.326 SD = mean stature - 1 percentile stature

$$SD = \frac{6.5"}{2.326} = 2.8" \text{ (71 mm)}$$

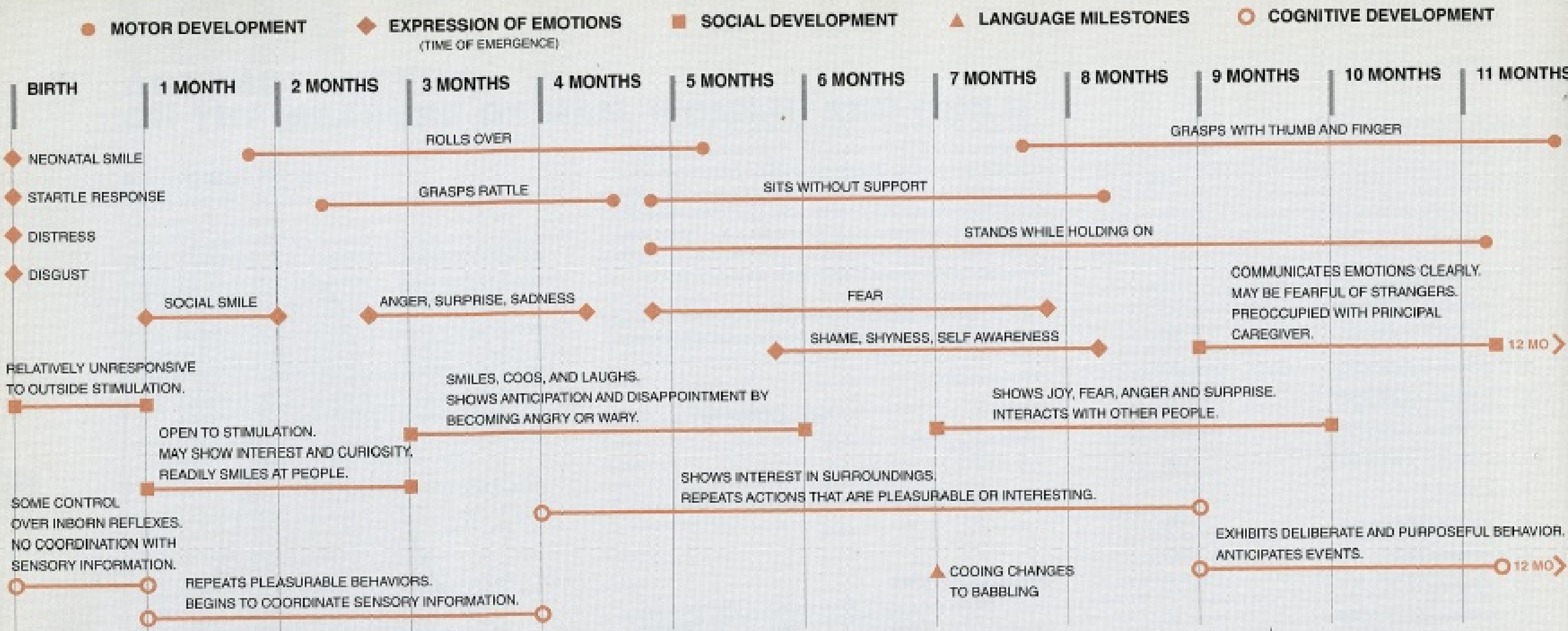
HUMAN VARIATIONS

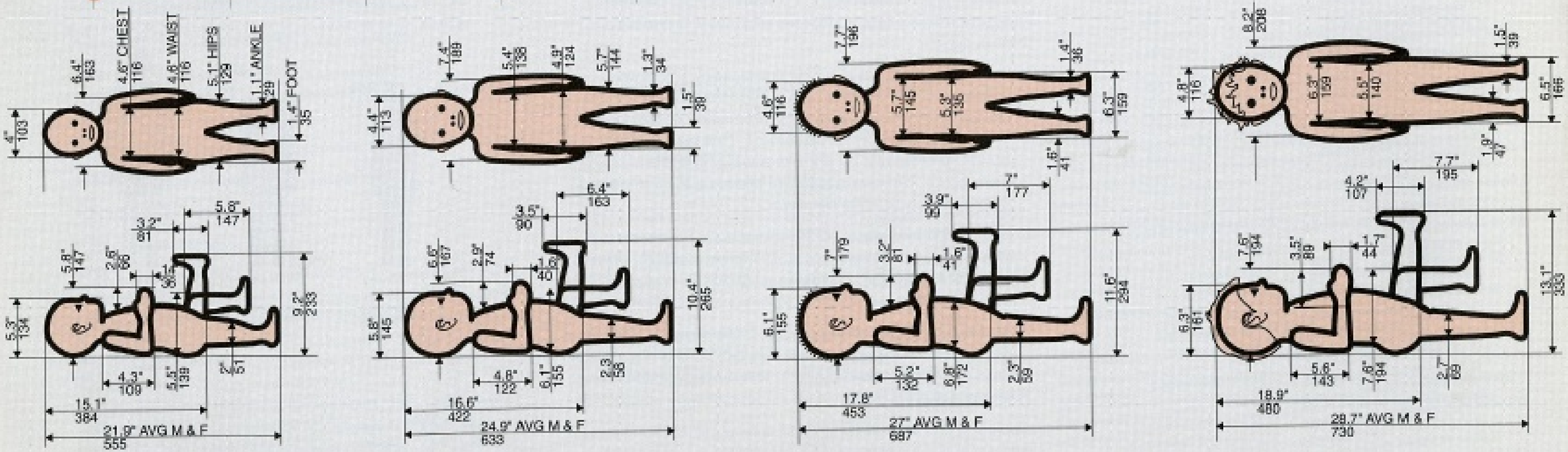
No two people are exactly alike, including identical twins. The great range of diversity is a problem for the designer. There are roughly three categories of human variability (NASA, 1978):

1. Intra-individual: sizes change during adult life. Some changes are due to aging and/or nutrition; others are caused by movement and/or the environment. The face and body are usually asymmetrical. This may be the reason some people do not like photographs of themselves; they are accustomed to seeing themselves in a mirror, which reverses the image.
2. Inter-individual: there are big differences due to sex and ethnic and racial membership. Differences include skin color, eye and hair color, body proportions, and other features.
3. Secular variability: changes occur from generation to generation for various reasons. However, since the pace of these changes is relatively slow, they have a limited effect on the designer.



FREQUENCY DISTRIBUTION CURVE



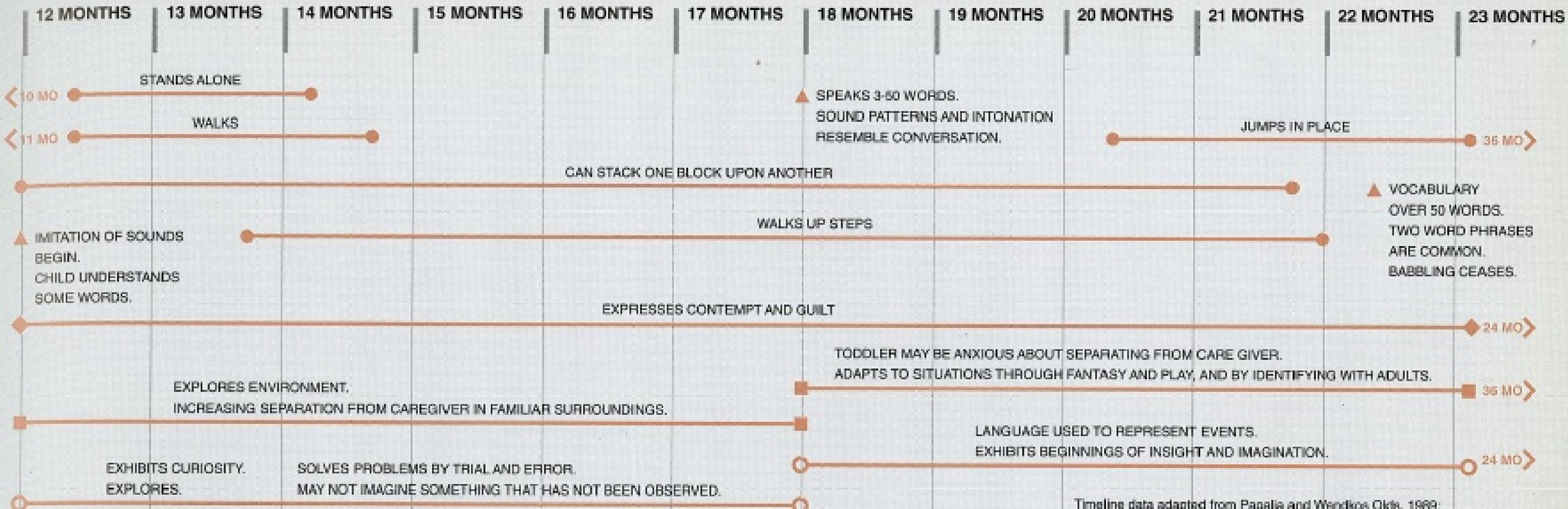


2 MONTHS
AVG WT: 10.3 LB - 4.7 KG

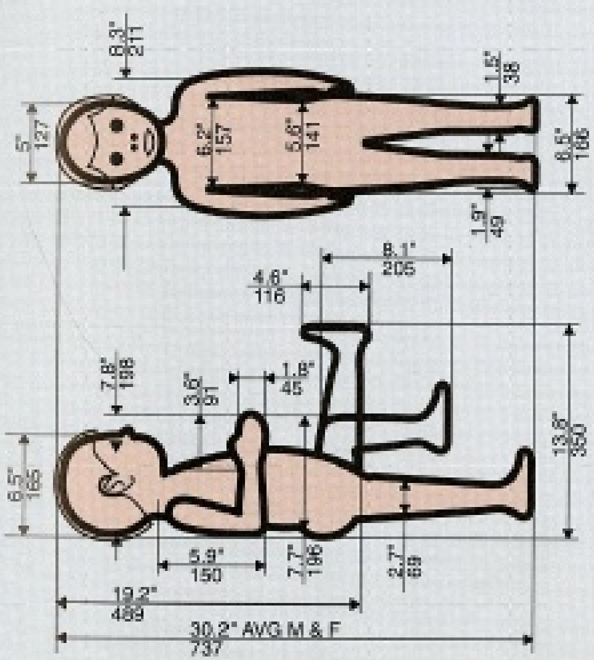
3-5 MONTHS
AVG WT: 14.7 LB - 6.7 KG

6-8 MONTHS
AVG WT: 17.6 LB - 8 KG

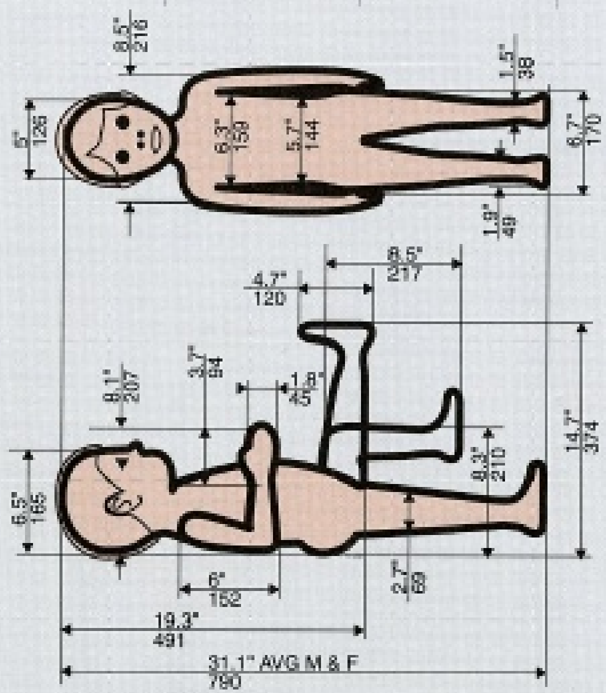
9-11 MONTHS
AVG WT: 20 LB - 9.1 KG



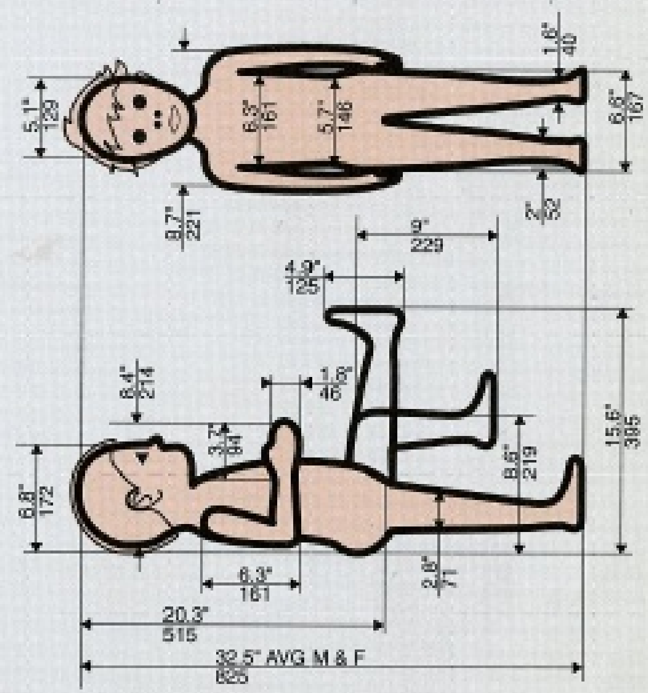
Timeline data adapted from Papalia and Wendkos Olds, 1989; pgs. 106, 136, 149, 153, 197, 208, 232, 266, and 272. Used with permission.



12-15 MONTHS
AVG WT: 22 LB - 10 KG



16-19 MONTHS
AVG WT: 23.3 LB - 10.6 KG



20-23 MONTHS
AVG WT: 25.5 LB - 11.6 KG

● MOTOR DEVELOPMENT

■ SOCIAL DEVELOPMENT

▲ LANGUAGE MILESTONES

○ COGNITIVE DEVELOPMENT

2.5 - 3 YEARS

● CANNOT TURN OR STOP SUDDENLY OR QUICKLY

● CAN JUMP A DISTANCE OF 15 TO 24 INCHES

● CAN ASCEND STAIRWAYS UNAIDED, ALTERNATING THE FEET

■ BEGINNINGS OF CONVERSATION; BREAKTHROUGH IN ATTENTION TO COMMUNICATION.

▲ NEW WORDS ARE LEARNED ALMOST EVERY DAY. COMPREHENSION IS EXCELLENT, ALTHOUGH CHILD STILL MAKES MANY MISTAKES IN GRAMMAR.

▲ VOCABULARY REACHES 1,000 WORDS, ABOUT 80% ARE INTELLIGIBLE. GRAMMAR IS CLOSE TO ADULT SPEECH, AND SYNTACTIC MISTAKES ARE FEWER.

○ GROUNDWORK FOR LOGICAL THINKING: CHILDREN CAN THINK ABOUT OBJECTS, PEOPLE, OR EVENTS IN THEIR ABSENCE BY USING MENTAL REPRESENTATIONS OF THEM, BUT THEY CANNOT YET MANIPULATE THESE REPRESENTATIONS. 6 YR

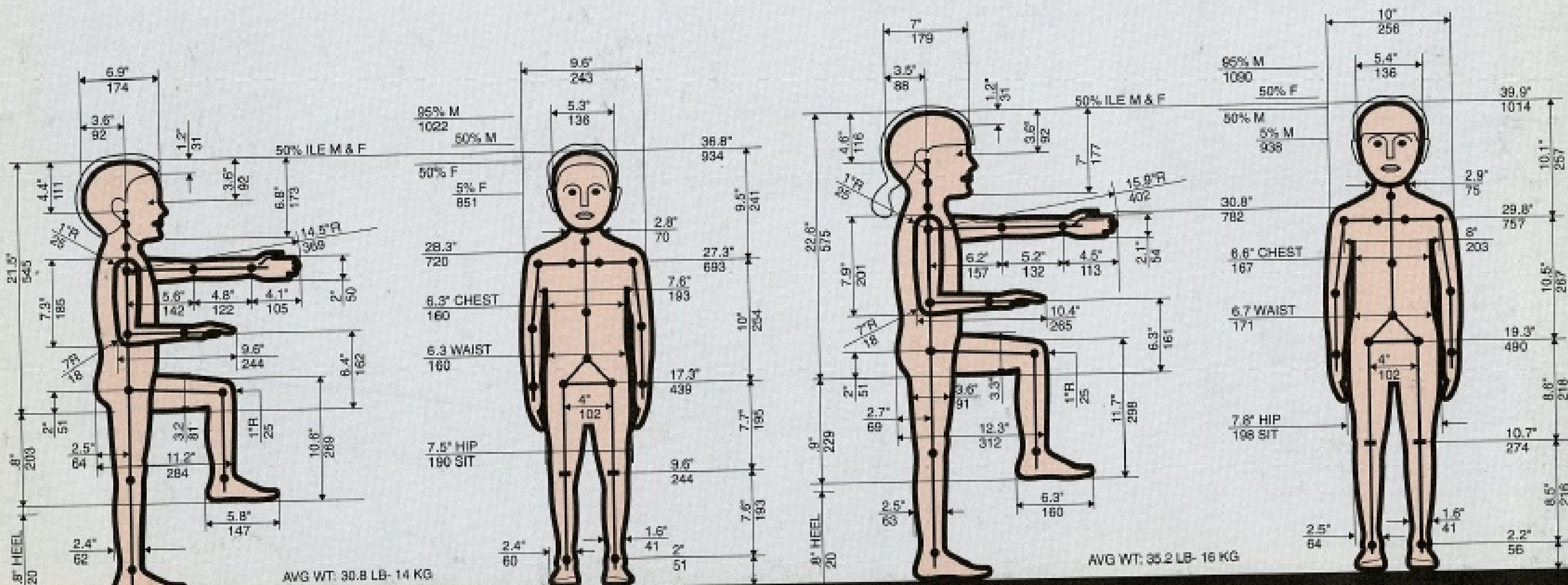
4 YEARS
GIRLS TALLER THAN BOYS

● MORE EFFECTIVE CONTROL OF STOPPING, STARTING, AND TURNING

● CAN JUMP A DISTANCE OF 24 OR 33 INCHES

● CAN DESCEND LONG STAIRWAYS ALTERNATING THE FEET, IF SUPPORTED

■ CHILD THINKS THAT HIS OR HER POINT OF VIEW IS THE ONLY ONE POSSIBLE 6 YR



5 YEARS

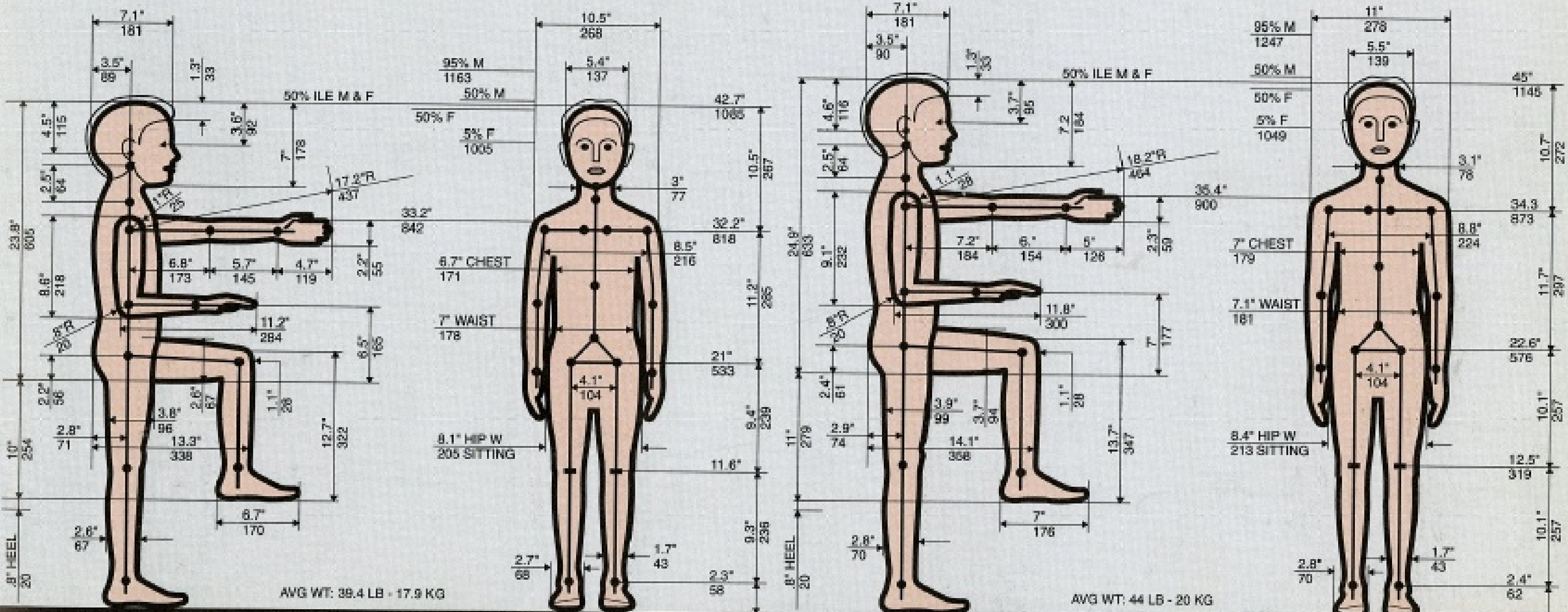
- CAN START, TURN, AND STOP EFFECTIVELY IN GAMES
- CAN MAKE A RUNNING JUMP OF 28 TO 38 INCHES
- CAN DESCEND LONG STAIRWAYS UNAIDED, ALTERNATING THE FEET

6 YEARS

- GIRLS ARE SUPERIOR IN ACCURACY OF MOVEMENT.
  BOYS ARE SUPERIOR IN FORCEFUL, LESS COMPLEX ACTS.
- CAN THROW WITH PROPER WEIGHT SHIFT AND STOP

4 YR — CHILD THINKS THAT HIS OR HER OWN POINT OF VIEW IS THE ONLY ONE POSSIBLE

3 YR — CHILD LEARNS NOT ONLY BY SENSING AND DOING, BUT BY THINKING AS WELL.
BASIC UNDERSTANDING OF CAUSE AND EFFECT.



● MOTOR DEVELOPMENT

■ SOCIAL DEVELOPMENT

○ COGNITIVE DEVELOPMENT

7 YEARS

- BALANCING ON ONE FOOT WITHOUT LOOKING BECOMES POSSIBLE
- CAN HOP AND JUMP ACCURATELY INTO SMALL SQUARES
- CAN ACCURATELY PERFORM JUMPING JACK EXERCISES

8 YEARS

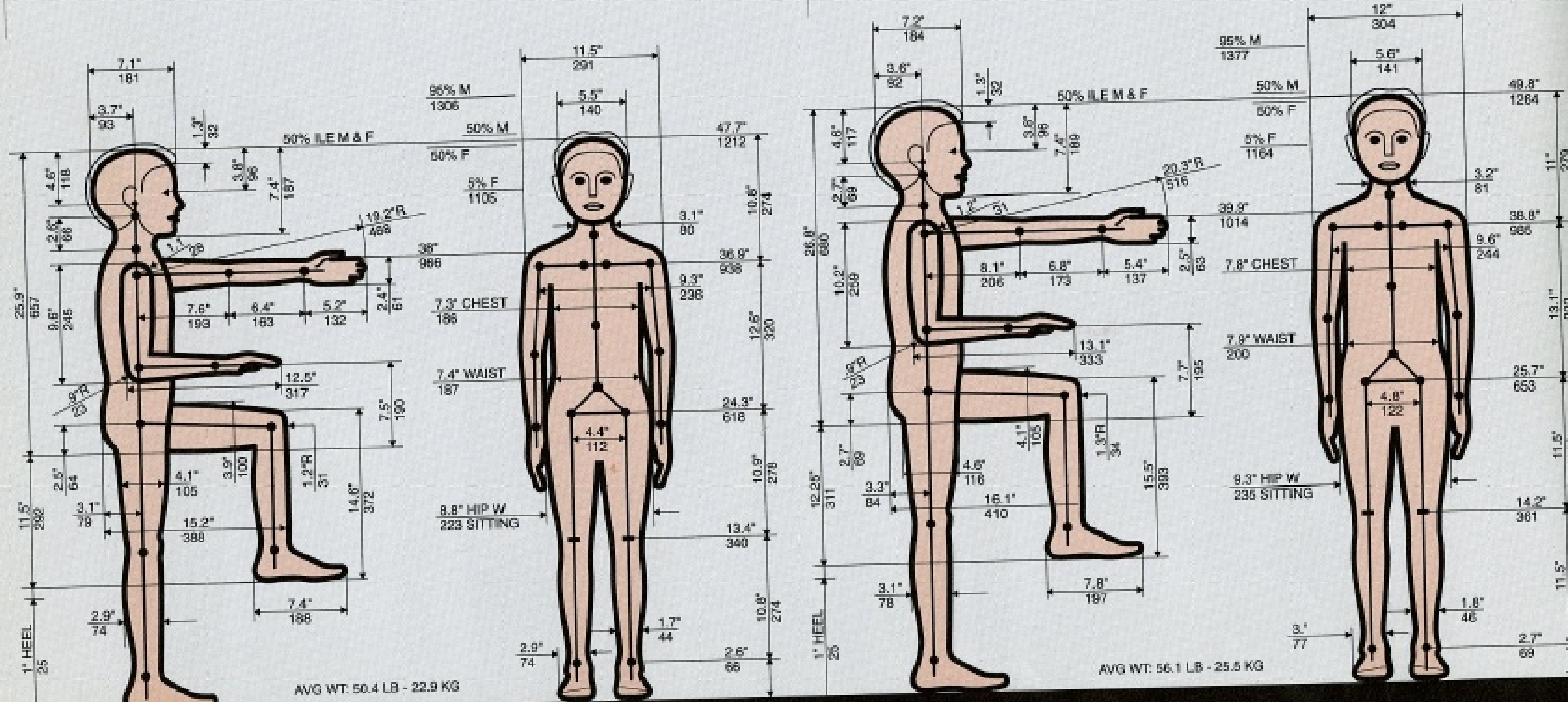
- GRIP STRENGTH PERMITS STEADY 12-POUND PRESSURE
- GIRLS CAN THROW A SMALL BALL 40 FEET

CHILD REALIZES THAT OTHERS MAY INTERPRET A SITUATION IN A WAY DIFFERENT FROM HIS OR HER OWN

6 YR

CHILDREN CAN THINK LOGICALLY ABOUT "HERE & NOW", BUT NOT YET ABOUT ABSTRACTIONS

10 YR



9 YEARS

- GIRLS CAN JUMP VERTICALLY TO A HEIGHT OF 8 1/2 INCHES; BOYS, 10 INCHES
- BOYS CAN RUN 16 1/2 FEET PER SECOND
- BOYS CAN THROW A BALL 70 FEET

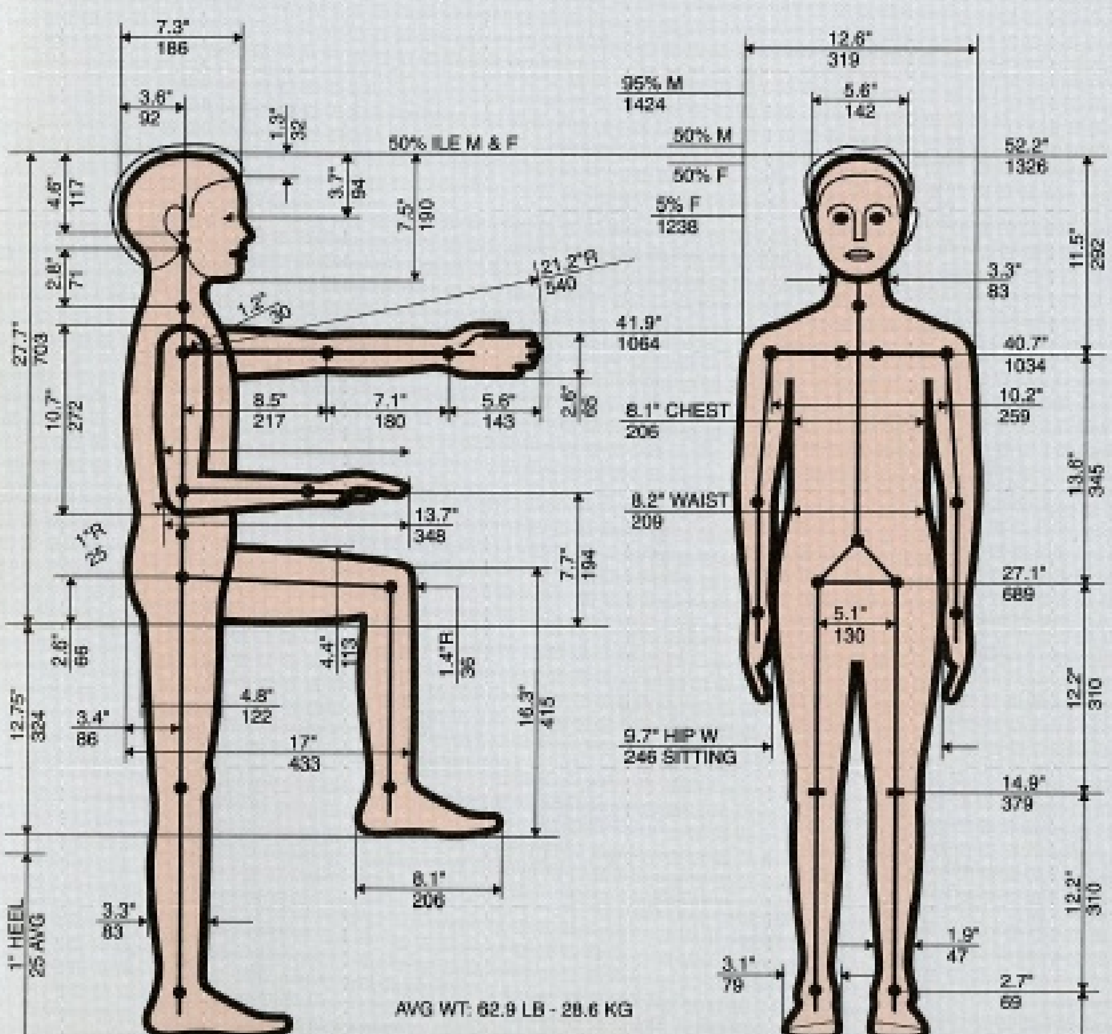
10 YEARS

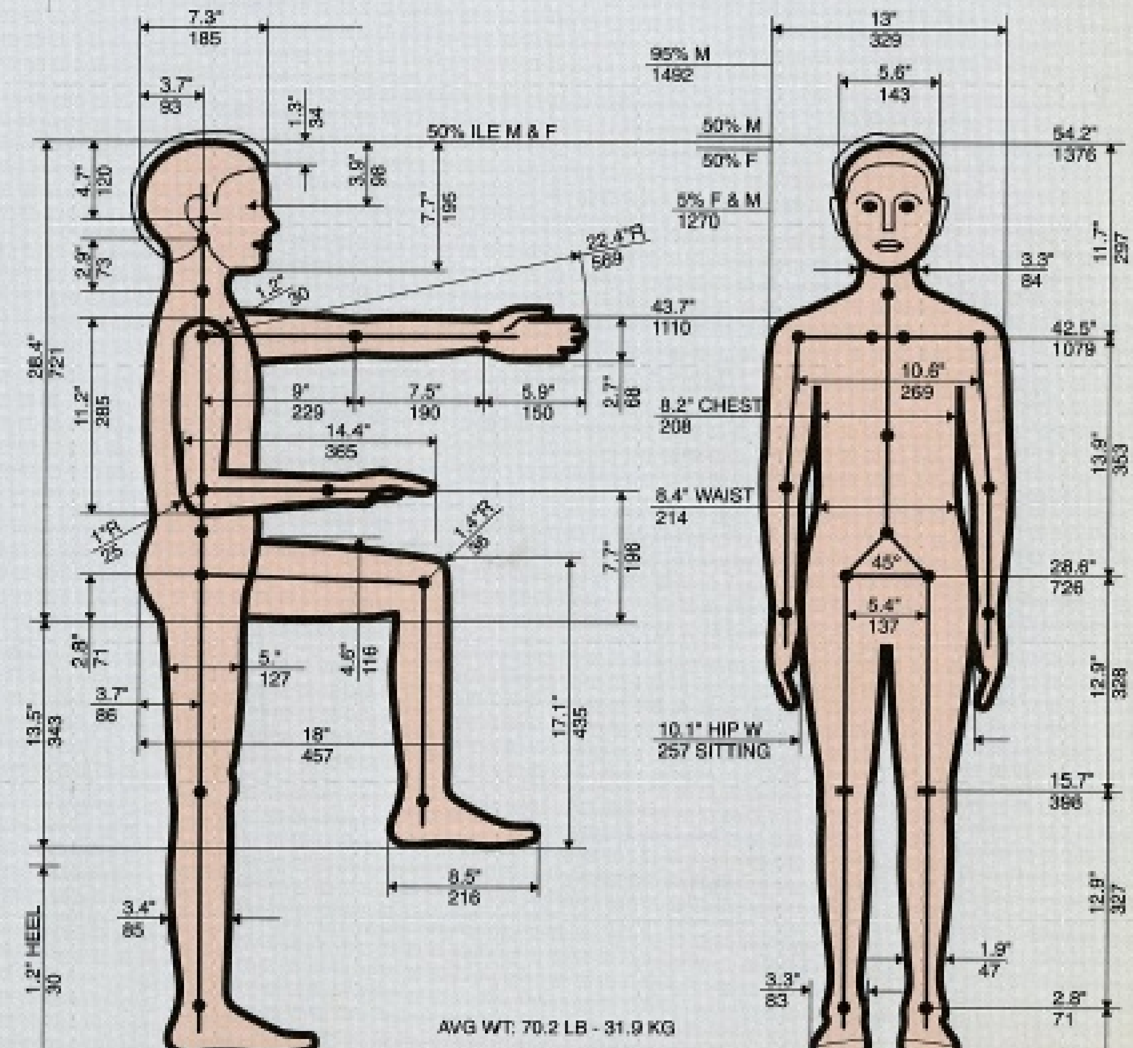
- CAN JUDGE AND INTERCEPT PATHWAYS OF SMALL BALLS THROWN FROM A DISTANCE
- GIRLS CAN RUN 17 FEET PER SECOND

8 YR — CHILD HAS RECIPROCAL AWARENESS, REALIZES OTHERS HAVE A POINT OF VIEW AND THAT OTHERS ARE AWARE THAT HE OR SHE HAS A PARTICULAR POINT OF VIEW.

CHILD UNDERSTANDS IMPORTANCE OF LETTING OTHERS KNOW THAT THEIR REQUESTS HAVE NOT BEEN IGNORED OR FORGOTTEN.

7 YR — GAINING PROFICIENCY AT CLASSIFYING, MANIPULATING NUMBERS, DEALING WITH CONCEPTS OF TIME AND SPACE, AND DISTINGUISHING REALITY FROM FANTASY





● MOTOR DEVELOPMENT ■ SOCIAL DEVELOPMENT ○ COGNITIVE DEVELOPMENT

11 YEARS
GIRLS TALLER THAN BOYS

● STANDING BROAD JUMP OF 5 FEET IS POSSIBLE FOR BOYS; 4 1/2 FEET FOR GIRLS.

12 YEARS
GIRLS TALLER THAN BOYS

● STANDING HIGH JUMP OF 3 FEET IS POSSIBLE

◄ 10 YR ■ CHILD CAN IMAGINE A THIRD PERSON'S PERSPECTIVE, TAKING INTO ACCOUNT SEVERAL DIFFERENT POINTS OF VIEW ■

ABILITY TO THINK ABSTRACTLY.

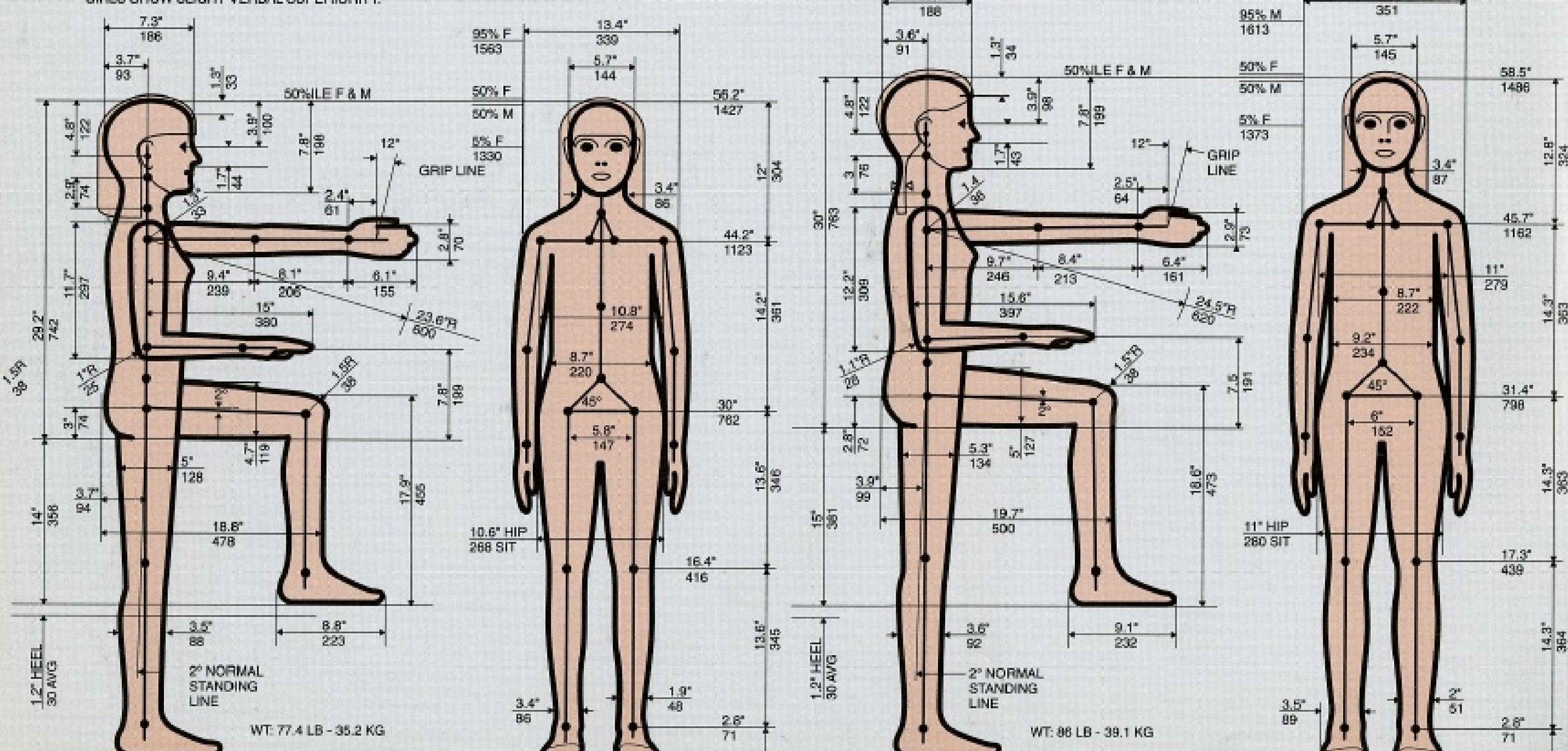
CAPAPABLE OF HYPOTHETICAL-DEDUCTIVE REASONING.

CAN BRING TO BEAR WHAT HAS BEEN LEARNED IN THE PAST TO SOLVE THE PROBLEMS OF THE PRESENT, AND PLAN FOR THE FUTURE.

○ ADULTHOOD ►

○ BOYS SHOW SLIGHT MATHEMATICAL AND SPATIAL SUPERIORITY.

GIRLS SHOW SLIGHT VERBAL SUPERIORITY.

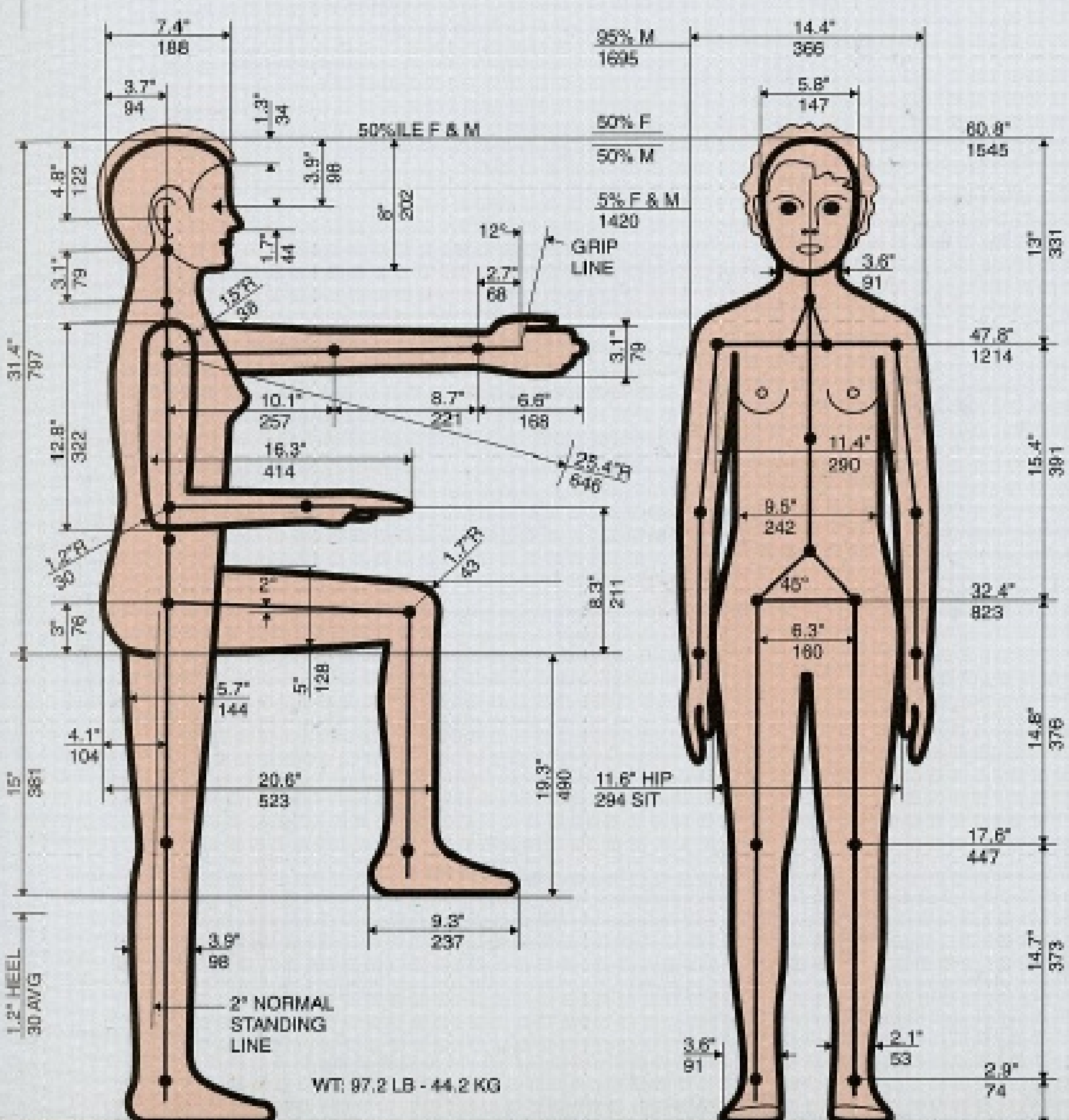


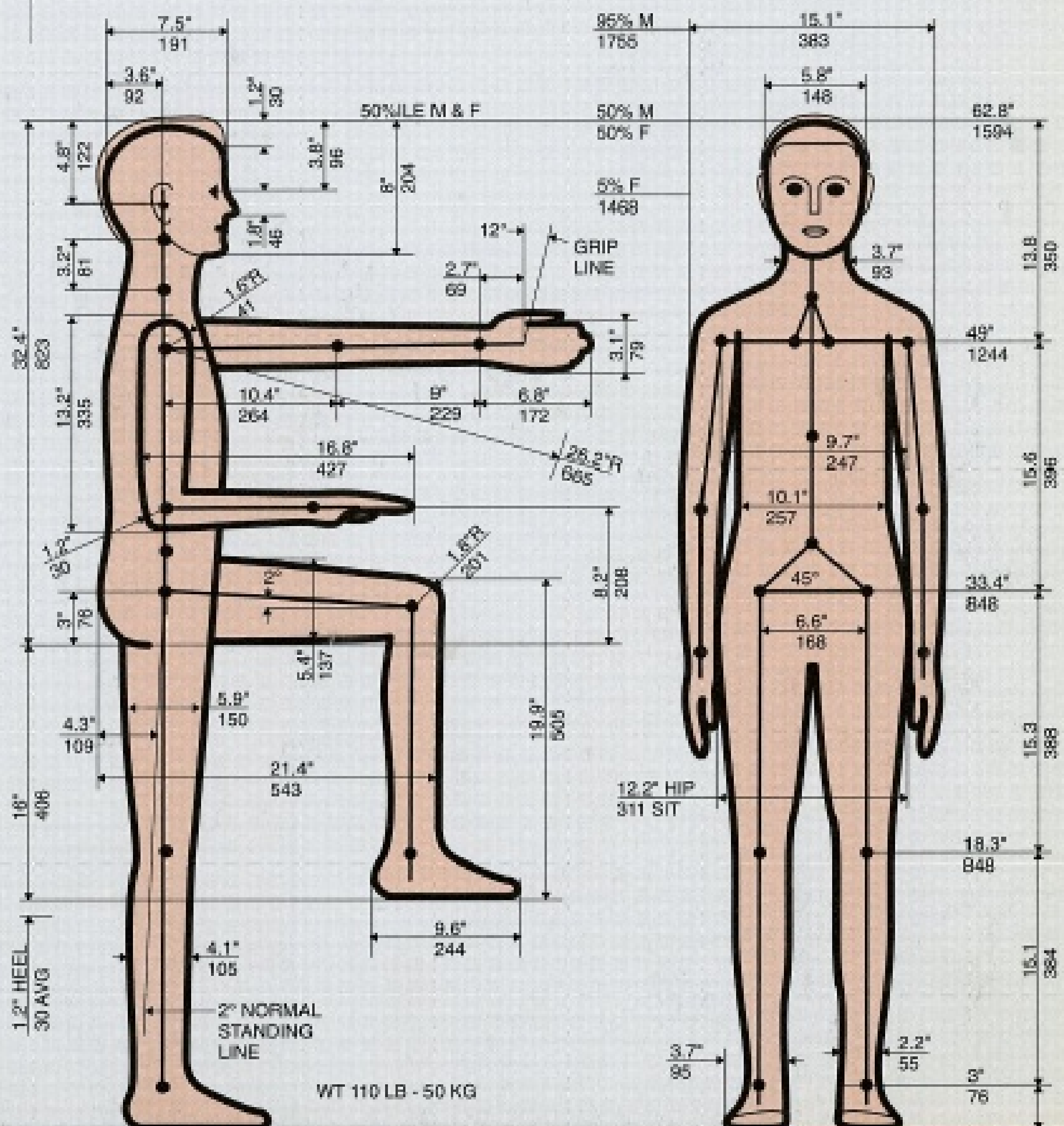
13 YEARS
GIRLS TALLER THAN BOYS

14 YEARS

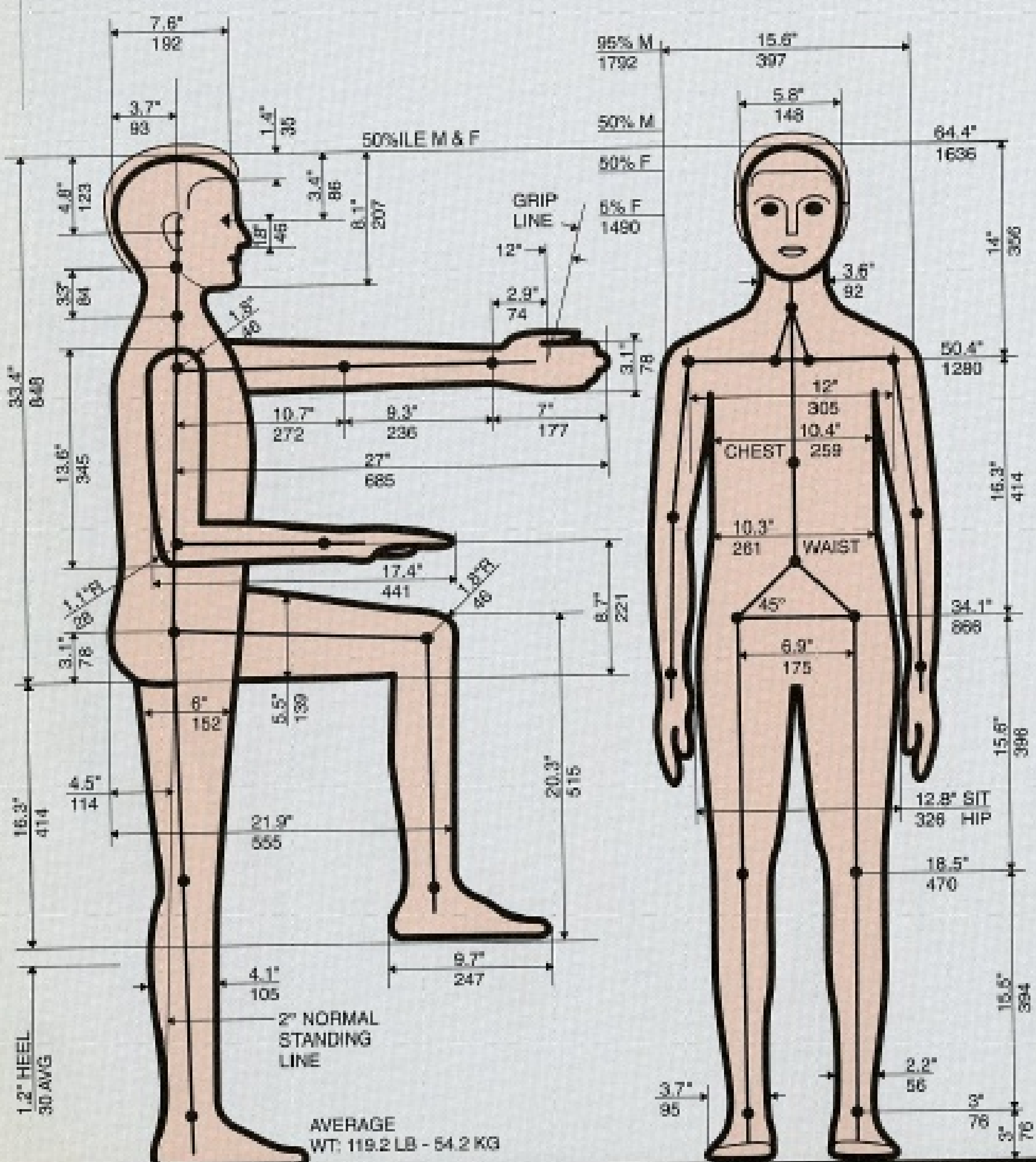
ADOLESCENCE: PERSON REALIZES THAT COMMUNICATION AND MUTUAL ROLE THINKING DO NOT ALWAYS RESOLVE DISPUTES OVER RIVAL VALUES

ADULTHOOD

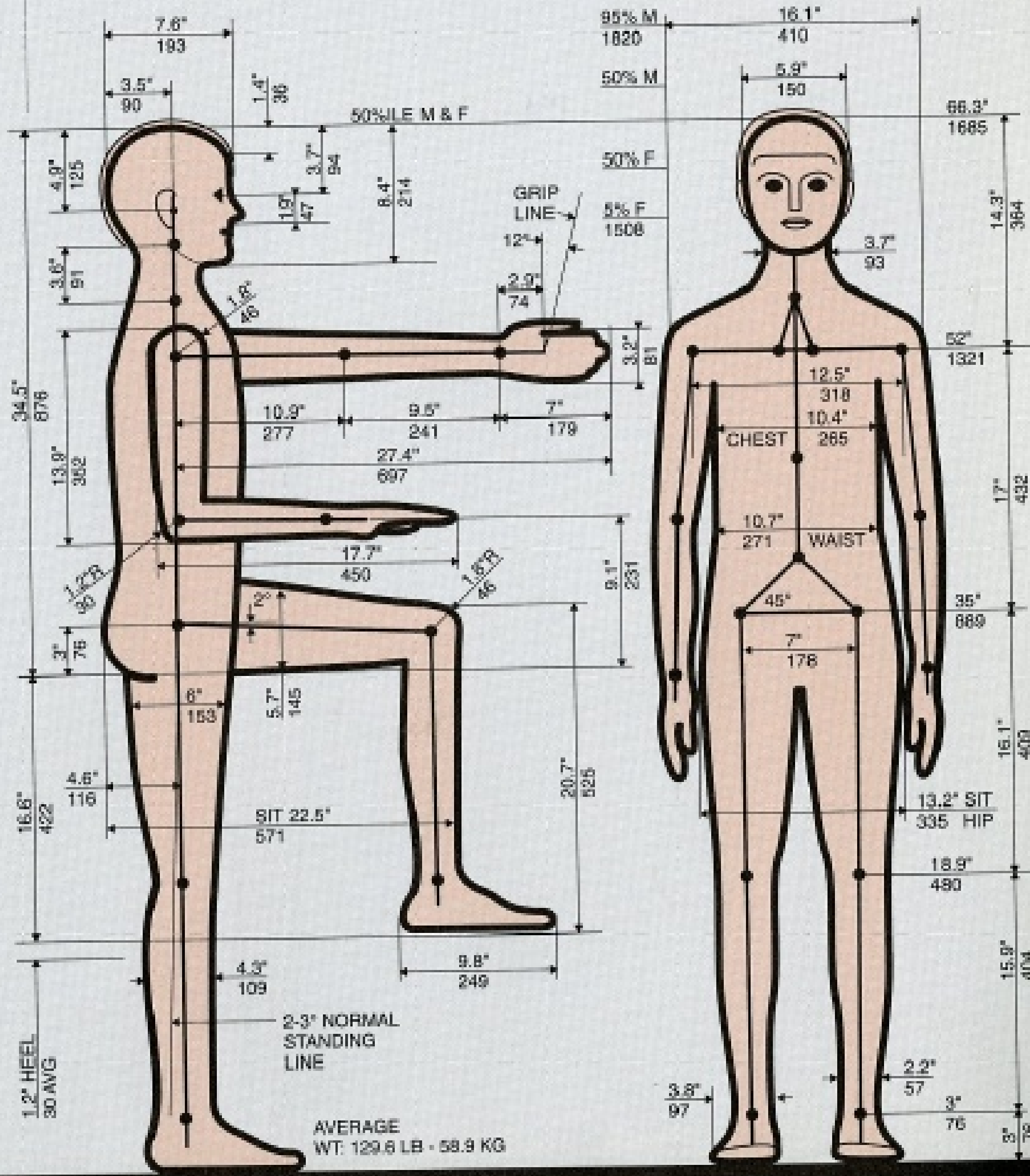




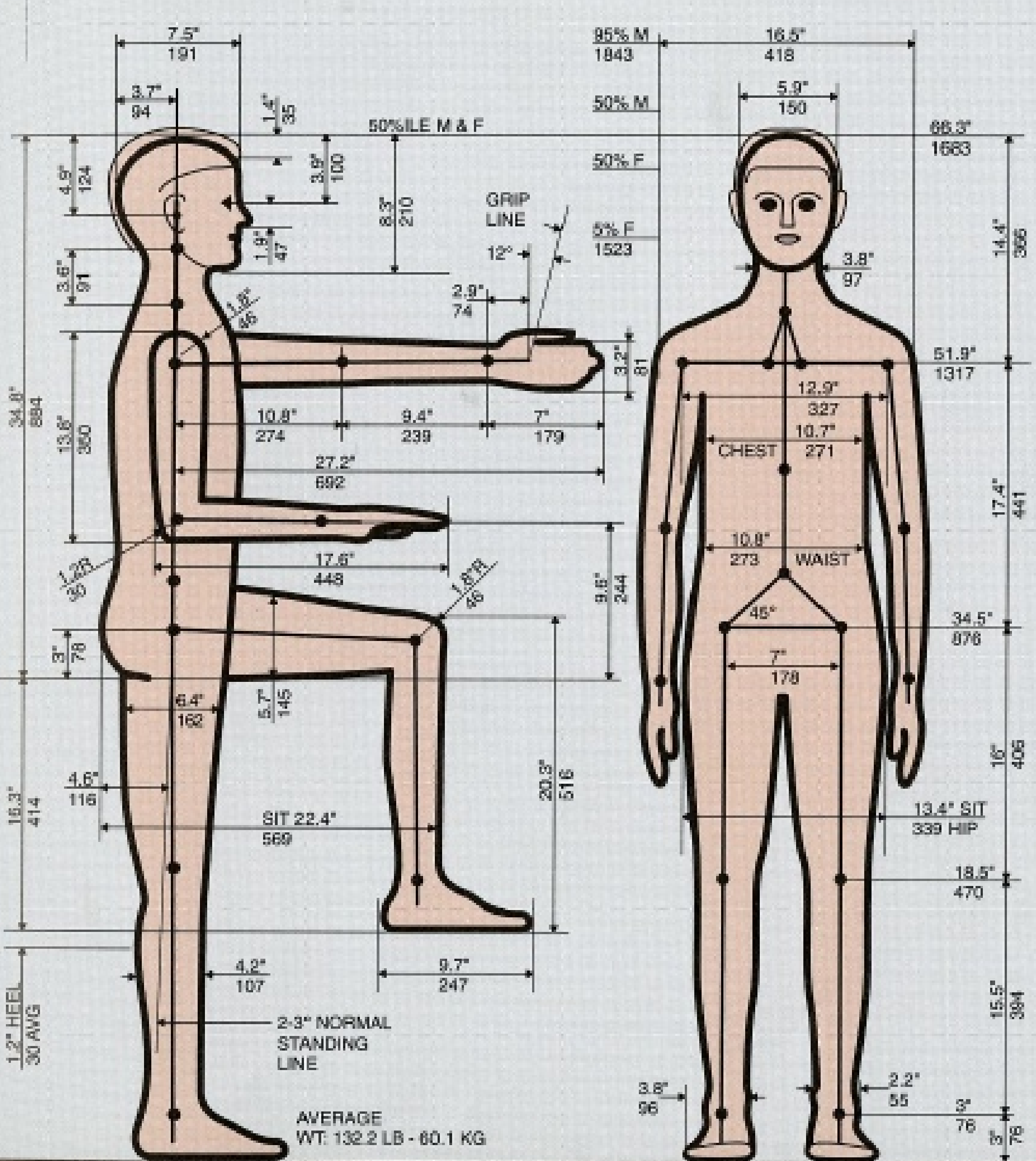
15 YEARS



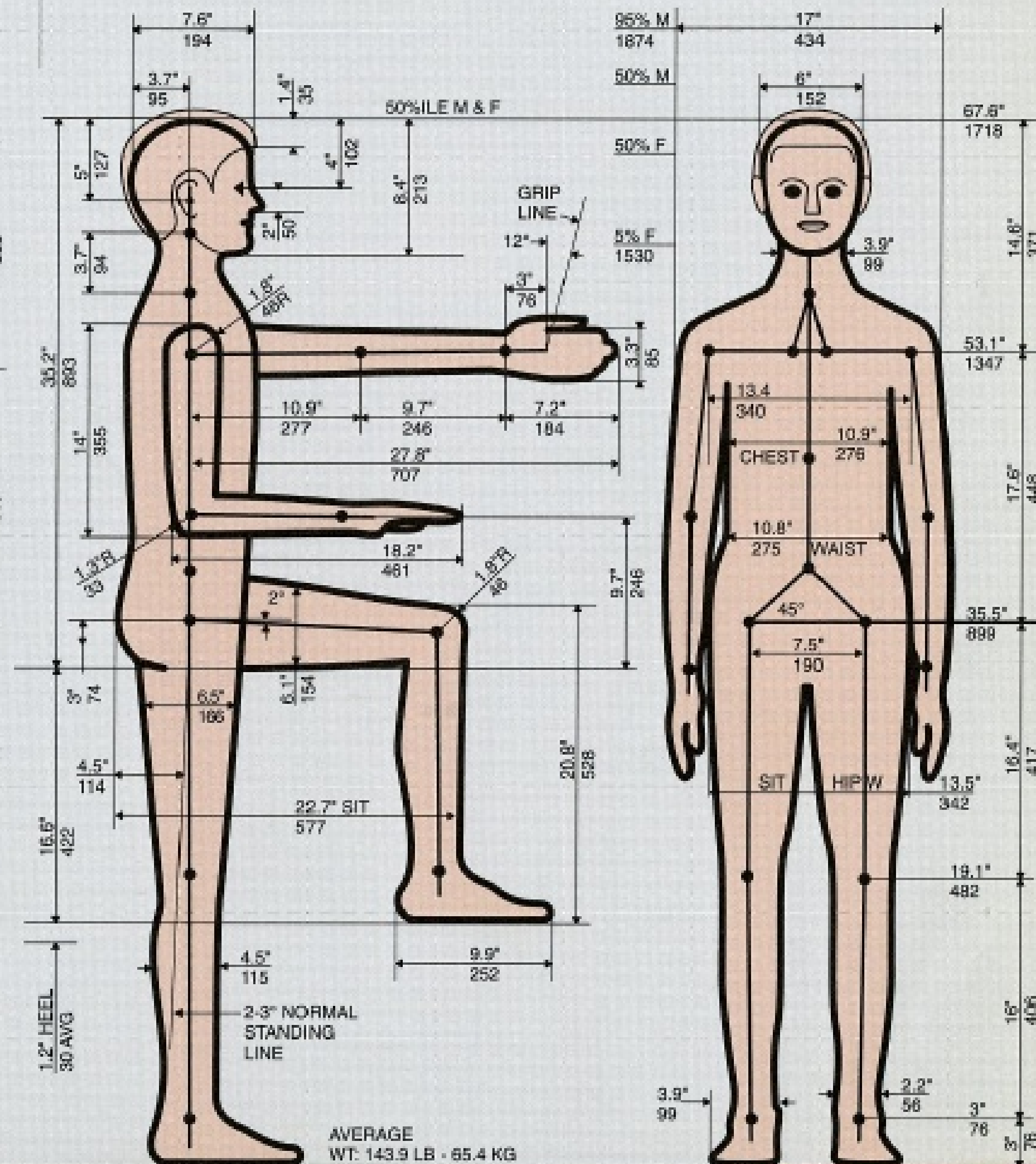
16 YEARS

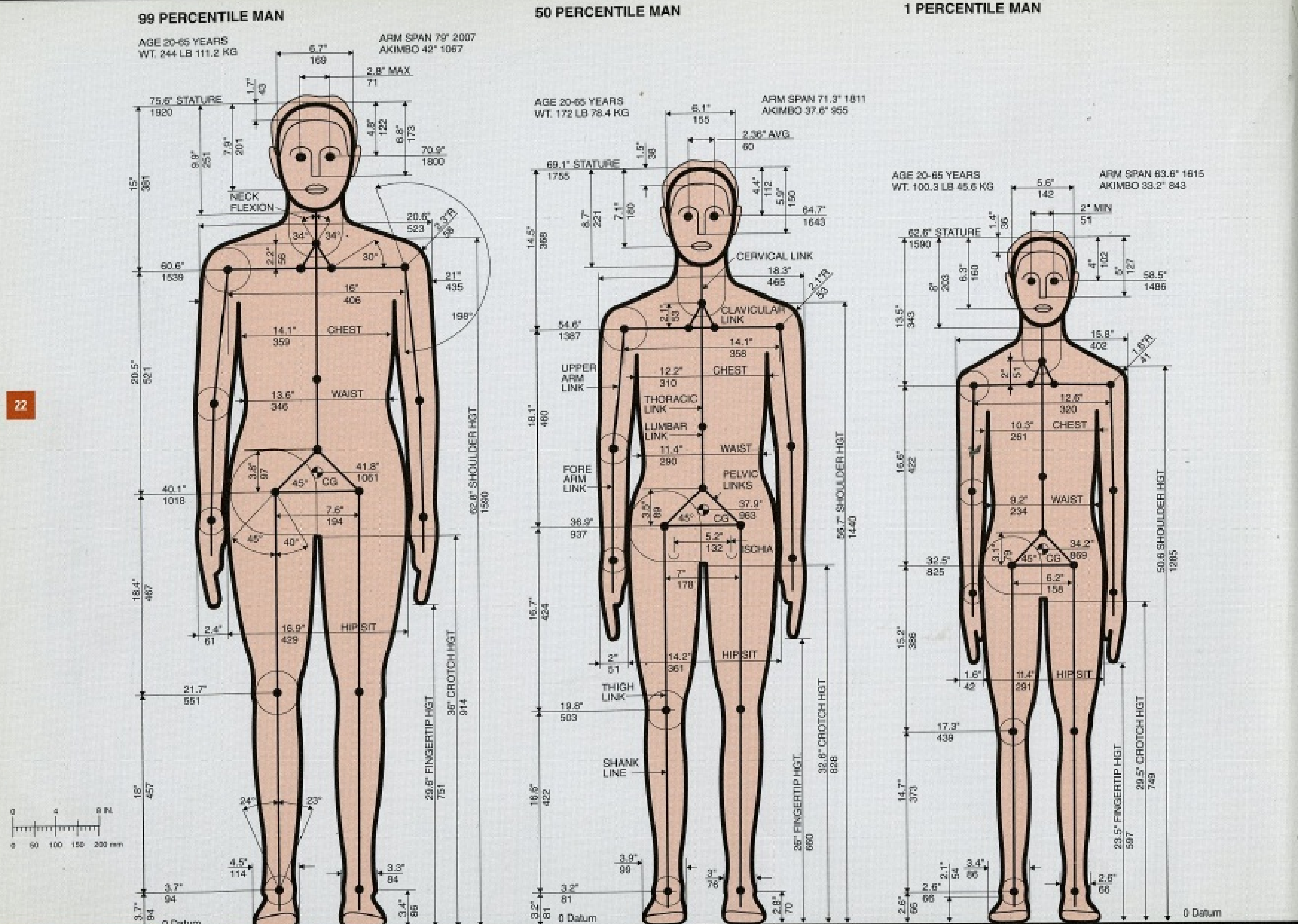


17 YEARS



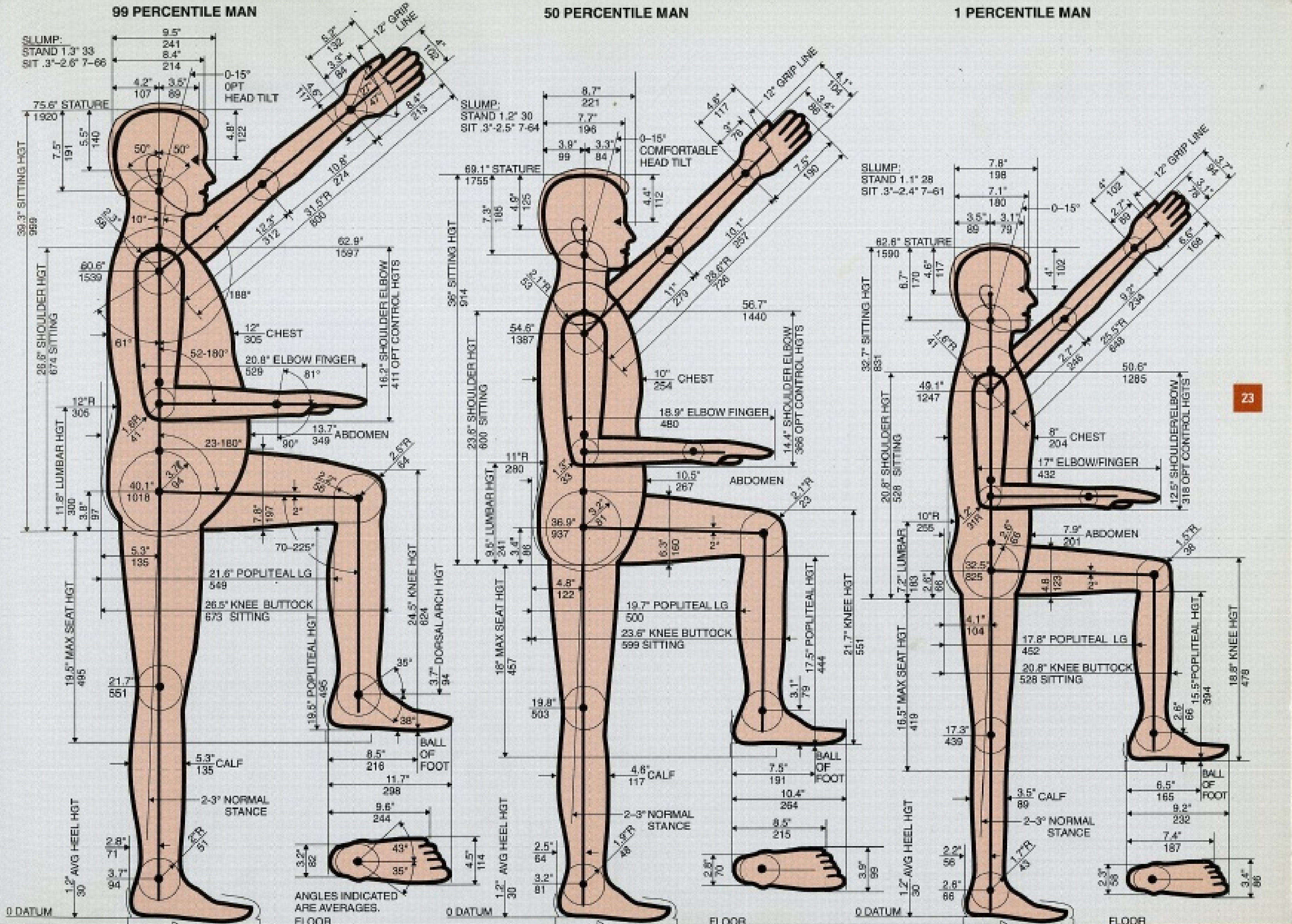
18 - 18.5 YEARS





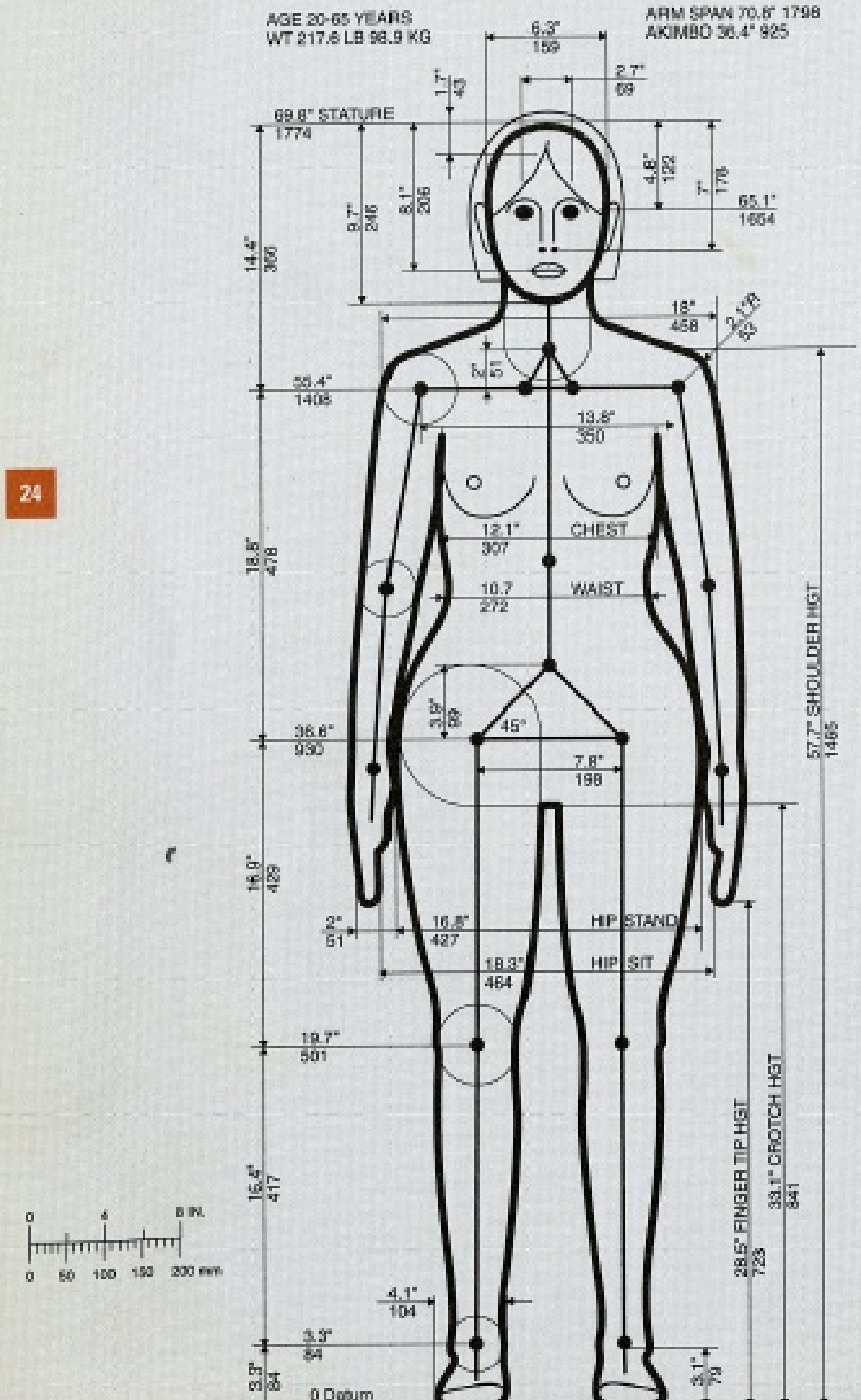
99 PERCENTILE MAN
AGE 20-65 YEARS
WT. 244 LB 111.2 KG
ARM SPAN 79" 2007
AKIMBO 42" 1067
75.6" STATURE 1920
NECK FLEXION
CHEST
WAIST
CG
HIP SIT
62.6" SHOULDER HGT 1590
36" CROTCH HGT 914
29.6" FINGERTIP HGT 751
0 Datum
50 PERCENTILE MAN
AGE 20-65 YEARS
WT. 172 LB 78.4 KG
ARM SPAN 71.3" 1811
AKIMBO 37.6" 955
69.1" STATURE 1755
2.36" AVG. 60
CERVICAL LINK
CLAVICULAR LINK
UPPER ARM LINK
THORACIC LINK
LUMBAR LINK
FORE ARM LINK
PELVIC LINKS
ISCHIA
THIGH LINK
SHANK LINE
56.7" SHOULDER HGT 1440
32.6" CROTCH HGT 828
26" FINGERTIP HGT. 660
0 Datum
1 PERCENTILE MAN
AGE 20-65 YEARS
WT. 100.3 LB 45.6 KG
ARM SPAN 63.6" 1615
AKIMBO 33.2" 843
62.6" STATURE 1590
2" MIN 51
50.6 SHOULDER HGT 1285
29.5" CROTCH HGT 749
23.5" FINGERTIP HGT 597
0 Datum
0 4 8 IN.
0 50 100 150 200 mm

22

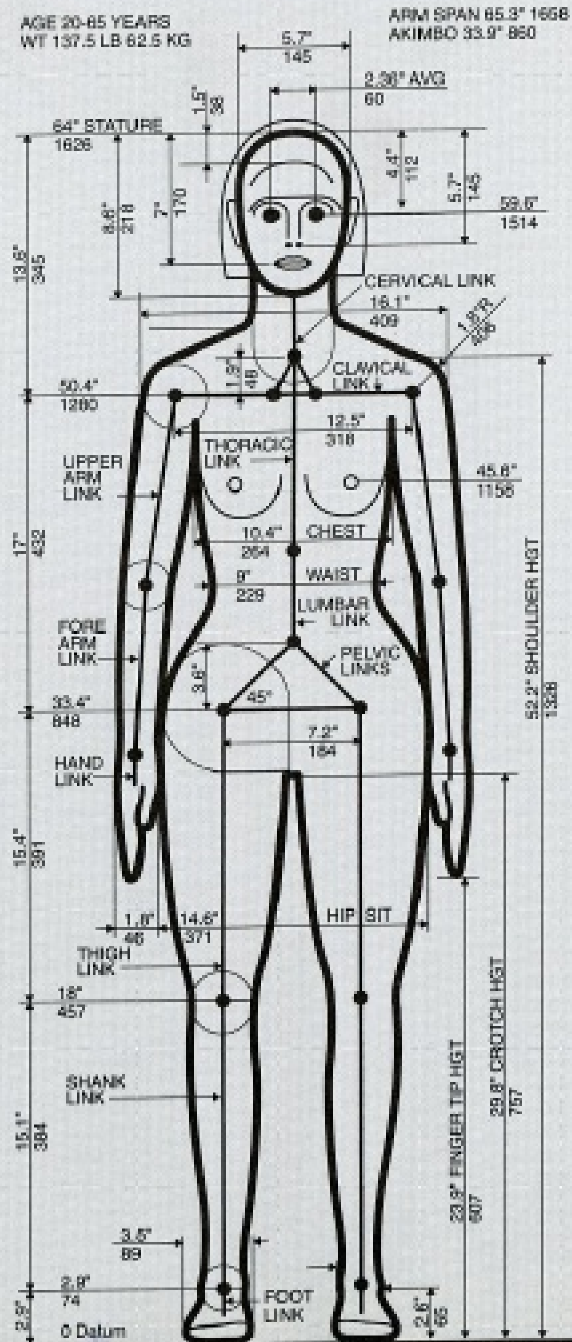

99 PERCENTILE MAN
50 PERCENTILE MAN
1 PERCENTILE MAN
SLUMP:
STAND 1.3" 33
SIT .3"–2.6" 7–66
75.6" STATURE
1920
39.3" SITTING HGT
999
0–15°
OPT
HEAD TILT
12" GRIP LINE
60.6"
1539
28.6" SHOULDER HGT
674 SITTING
12" CHEST
305
20.8" ELBOW FINGER
529
16.2" SHOULDER ELBOW
411 OPT CONTROL HGTS
13.7" ABDOMEN
349
11.8" LUMBAR HGT
300
40.1"
1018
21.6" POPLITEAL LG
549
26.5" KNEE BUTTOCK
673 SITTING
19.5" MAX SEAT HGT
495
24.5" KNEE HGT
624
DORSAL ARCH HGT
19.5" POPLITEAL HGT
495
21.7"
551
5.3" CALF
135
2-3° NORMAL STANCE
BALL OF FOOT
1.2" AVG HEEL HGT
30
ANGLES INDICATED ARE AVERAGES.
0 DATUM
FLOOR
SLUMP:
STAND 1.2" 30
SIT .3"-2.5" 7-64
69.1" STATURE
1755
36" SITTING HGT
914
0–15°
COMFORTABLE HEAD TILT
12" GRIP LINE
54.6"
1387
23.6" SHOULDER HGT
600 SITTING
56.7"
1440
10" CHEST
254
18.9" ELBOW FINGER
480
14.4" SHOULDER ELBOW
366 OPT CONTROL HGTS
ABDOMEN
9.5" LUMBAR HGT
241
36.9"
937
19.7" POPLITEAL LG
500
23.6" KNEE BUTTOCK
599 SITTING
18" MAX SEAT HGT
457
17.5" POPLITEAL HGT
444
21.7" KNEE HGT
551
19.8"
503
4.6" CALF
117
2–3° NORMAL STANCE
BALL OF FOOT
1.2" AVG HEEL HGT
30
0 DATUM
FLOOR
SLUMP:
STAND 1.1" 28
SIT .3"–2.4" 7–61
62.8" STATURE
1590
32.7" SITTING HGT
831
0–15°
12" GRIP LINE
49.1"
1247
20.8" SHOULDER HGT
528 SITTING
50.6"
1285
8" CHEST
204
17" ELBOW/FINGER
432
12.5" SHOULDER/ELBOW
318 OPT CONTROL HGTS
7.9" ABDOMEN
201
7.2" LUMBAR
183
32.5"
825
17.8" POPLITEAL LG
452
20.8" KNEE BUTTOCK
528 SITTING
16.5" MAX SEAT HGT
419
15.5" POPLITEAL HGT
394
18.8" KNEE HGT
478
17.3"
439
3.5" CALF
89
2–3° NORMAL STANCE
BALL OF FOOT
1.2" AVG HEEL HGT
30
0 DATUM
FLOOR

23

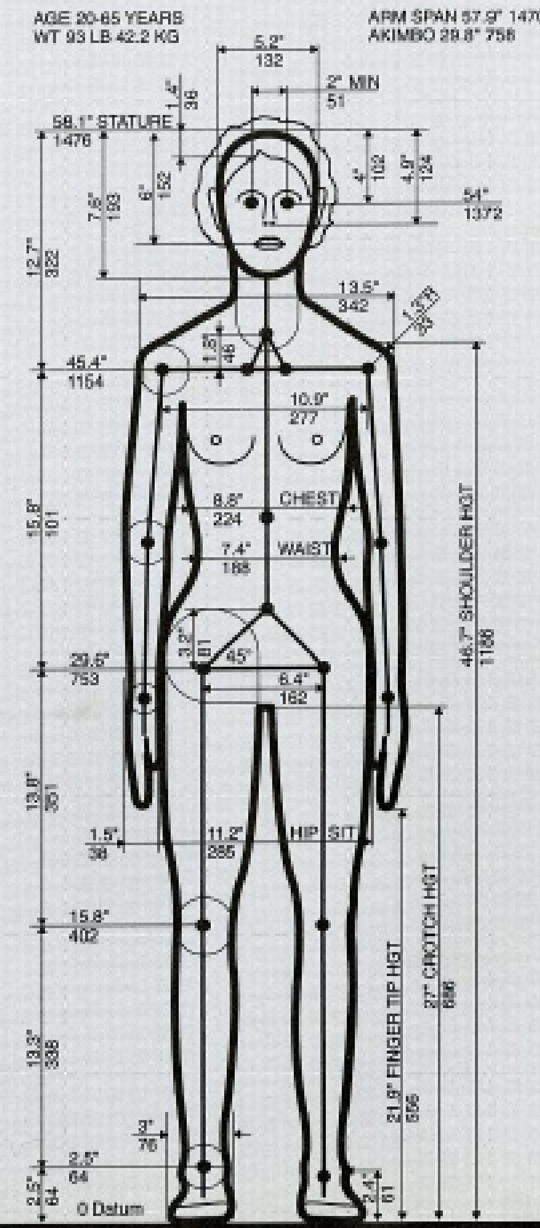
99 PERCENTILE WOMAN



50 PERCENTILE WOMAN

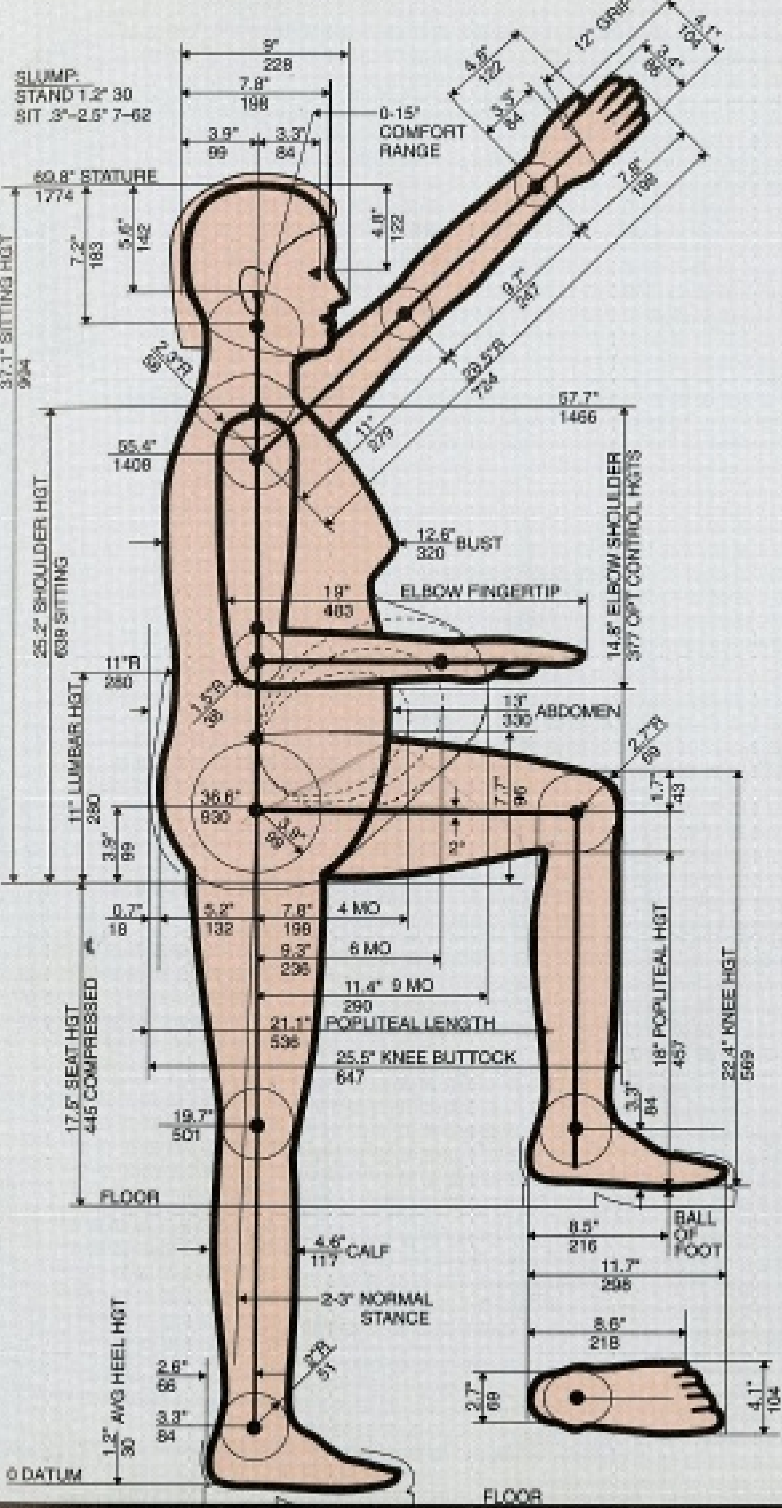


1 PERCENTILE WOMAN

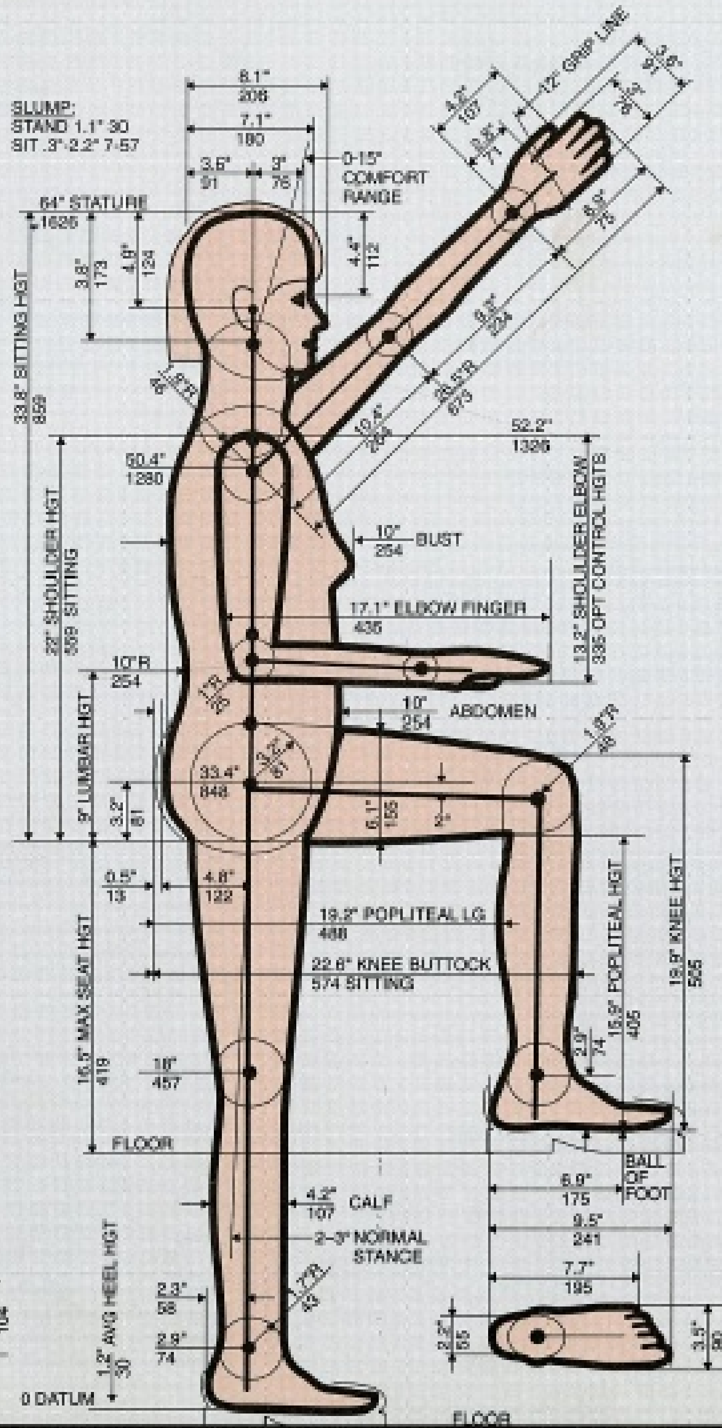


 THE MEASURE OF WOMAN (FRONT VIEW)

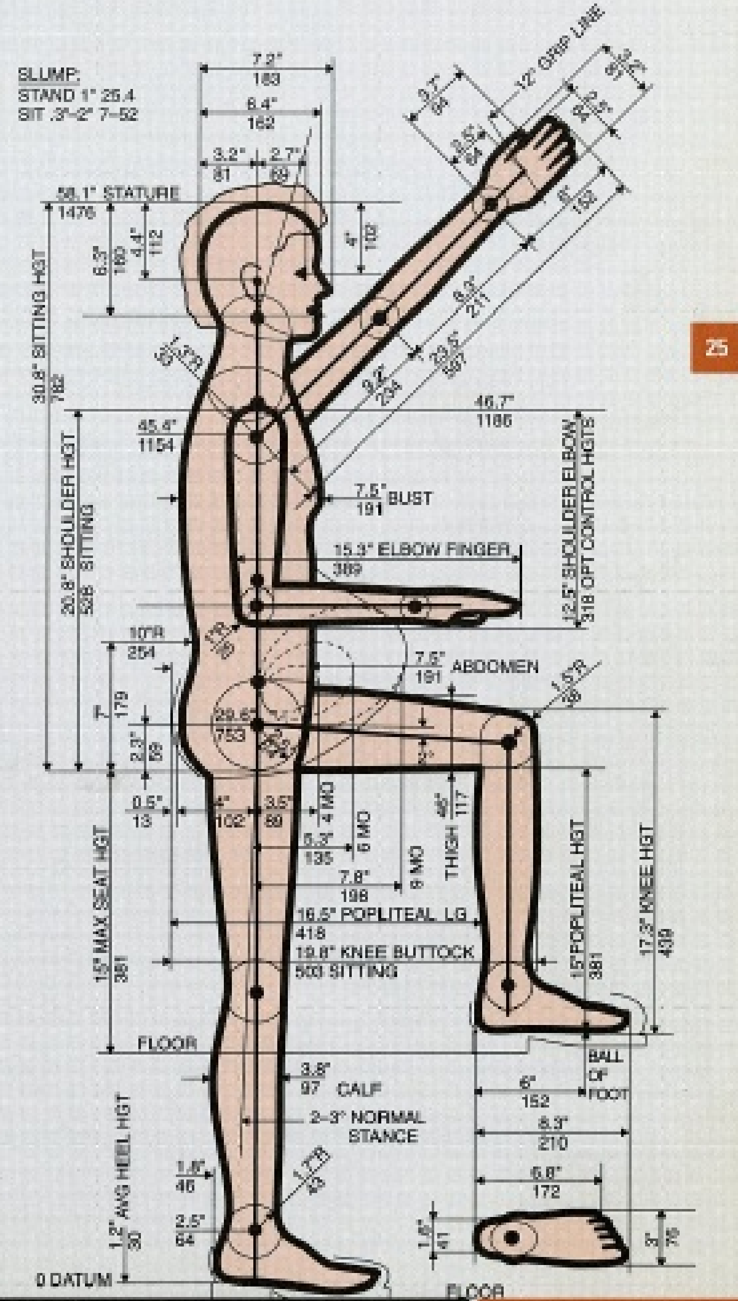
99 PERCENTILE WOMAN



50 PERCENTILE WOMAN



1 PERCENTILE WOMAN



25

Americans have been growing taller by approximately 0.4" (1 cm) per decade since 1920, which is similar to the growth rate in Europe. (Earlier data must be brought up to date.) The data for the last decade is difficult to assess because of the immigration of many shorter people. The anthropometric data in this book is designed to include 98% of the U.S. population (the 99, 50, and 1 percentiles are included for men and women). It has been said that the U.S. population "has the most diverse ethnic and racial mix of any country in the world." However, it does not represent the world population; for example, Japanese women smaller than the Japanese 15 percentile would not even be included in a U.S. study, because the 1 percentile Japanese woman is 2.3" (58 mm) shorter than the 1 percentile American woman.

American and Canadian farmers are taller than the 99 percentile U.S. male. This particular group's 95 percentile stature of 75.6" (1920 mm) coincides with the 99 percentile U.S. population stature. The sitting heights are the same, so that means that the group's leg lengths are about 1.7" (43 mm) longer (Casey, 1989).

There are proportional differences in body structure of several racial groups in the U.S. male population. The differences in select dimensions for white, black, and Japanese males are shown below (*Humanscale 1/2/3*, 1974).

Total Leg Lengths	
White	Mean
Black	Mean + 1.5" (38 mm)
Japanese	Mean - 3.6" (91 mm)

Total Arm Lengths	
White	Mean
Black	Mean + 0.6" (15 mm)
Japanese	Mean - 2" (51 mm)

Sitting Heights (crown to seat)	
White	Mean
Black	Mean - 1.5" (38 mm)
Japanese	Mean (almost as high)

Seat Heights (average male)	
White	17.5" (444 mm)
Black	18" (457 mm)
Japanese	15.8" (400 mm)

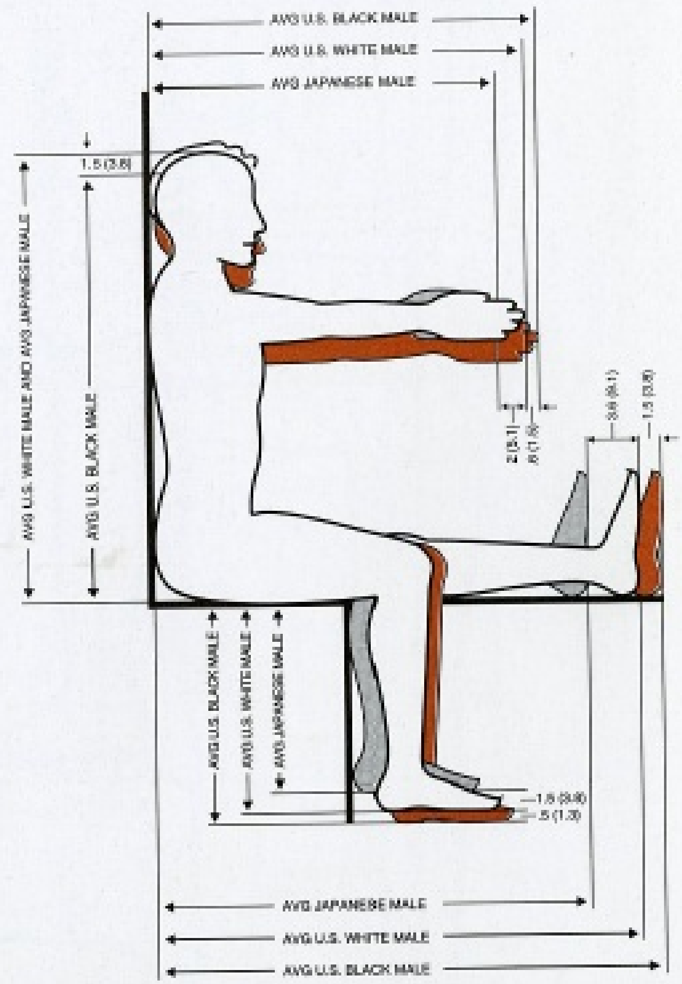
The following table indicates the diversity of the world population. This survey was put together in 1962, before the additions for the growth rates per decade.

Mean Values

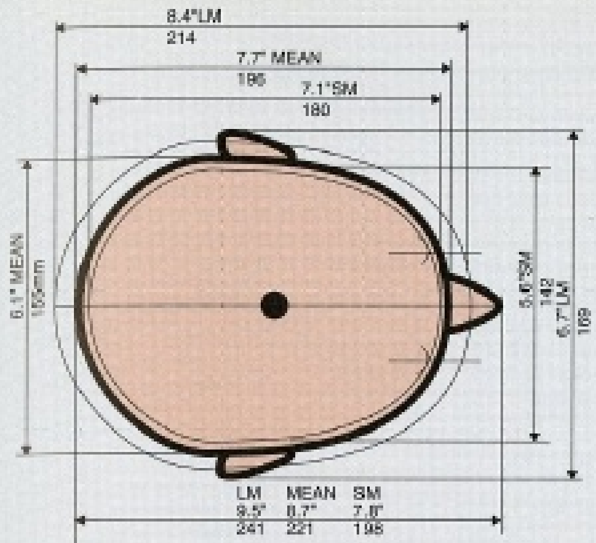
Populations	Stature in	Stature mm	Weight lbs	Weight kg
White				
Finland	67.3	1710	154.4	70.0
U.S. Army	68.5	1739	154.8	70.2
Iceland	68.3	1736	150.2	68.1
France	67.9	1725	147.7	67.0
England	65.5	1663	142.2	64.5
Sicily	66.6	1691	143.3	65.0
Morocco	66.5	1689	140.7	63.8
Scotland	67.1	1704	136.3	61.8
Tunisia	68.3	1734	137.4	62.3
Berbers	66.9	1698	131.2	59.5
Mahratta (India)	64.5	1638	122.8	55.7
Bengal (India)	65.3	1658	116.2	52.7
Black				
Yambasa	66.5	1690	136.7	62.0
Kirdi	65.6	1665	126.4	57.3
Baya	64.2	1630	118.9	53.9
Batutsi	69.3	1760	125.7	57.0
Kikuyu	64.8	1645	114.4	51.9
Pygmies	56.0	1422	88.0	39.9
Efe	56.6	1438	87.8	39.8
Bushmen	61.3	1558	89.1	40.4
Asian				
Turkestan	64.2	1631	153.7	69.7
Eskimo	63.5	1612	138.7	62.9
North China	66.1	1680	134.5	61.0
Korea	63.4	1611	122.4	55.5
Central China	64.2	1630	120.6	54.7
Japan	63.4	1609	116.9	53.0
Sudanese	62.9	1598	114.4	51.9
Annamites	62.5	1587	113.1	51.3
Hong Kong	65.4	1662	115.1	52.2

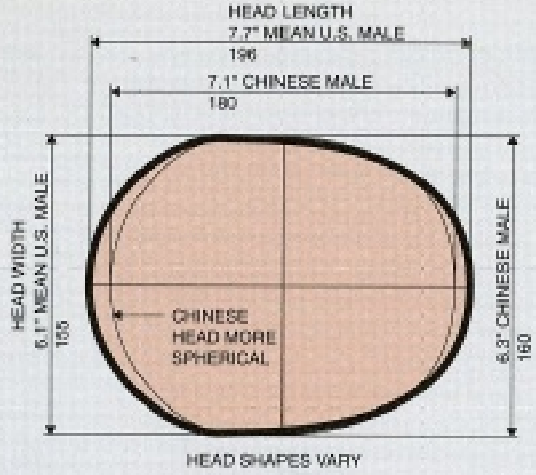
(Source: NASA, 1978)

From this table we can see how difficult it would be to accommodate the entire world population. At this time we must exclude a percentage of very small and very tall people. A 98% inclusion of the U.S. population appears satisfactory for design work.



PROPORTIONAL DIFFERENCES BETWEEN ETHNIC GROUPS



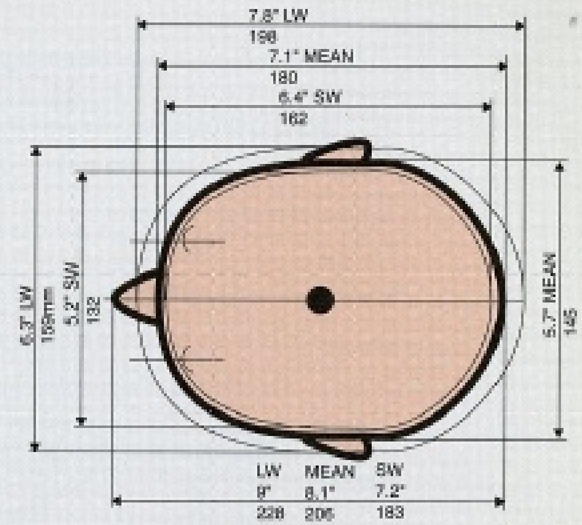


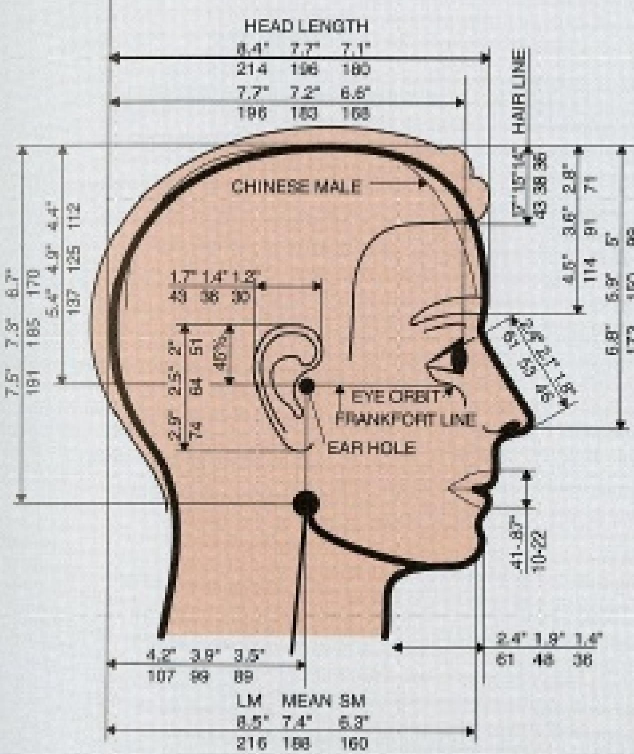
COMPARISON OF HEAD SIZES FOR AVERAGE MEN IN VARIOUS NATIONS

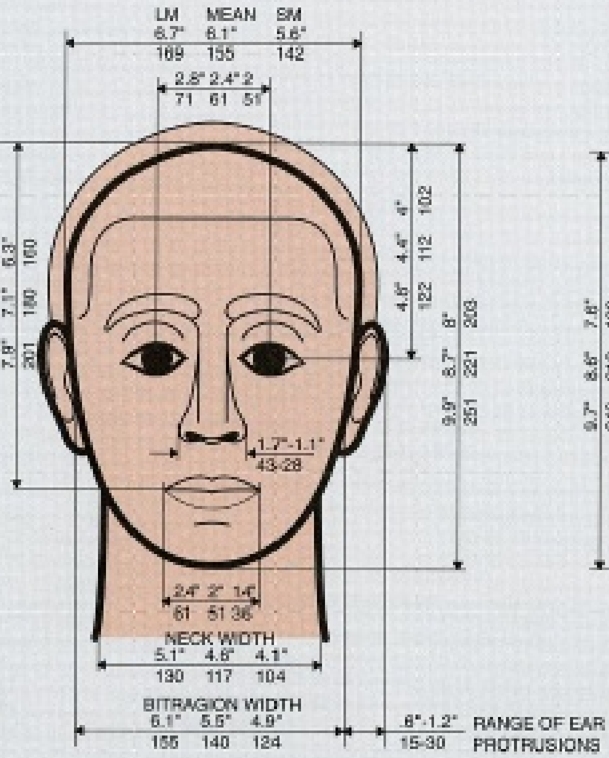
NATION	LENGTH	WIDTH
USA	7.7" (196)	6.1" (155)
GERMANY	7.7" (196)	6.1" (155)
ITALY	7.6" (193)	6.1" (155)
FRANCE	7.5" (191)	5.9" (150)
JAPAN	7.3" (185)	6.1" (155)
CHINA	7.1" (180)	6.3" (160)

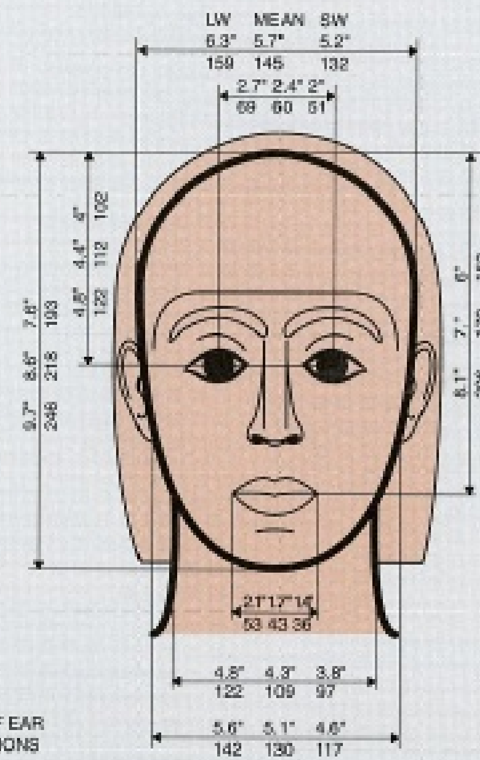
LM = 99 PERCENTILE MAN
SM = 1 PERCENTILE MAN

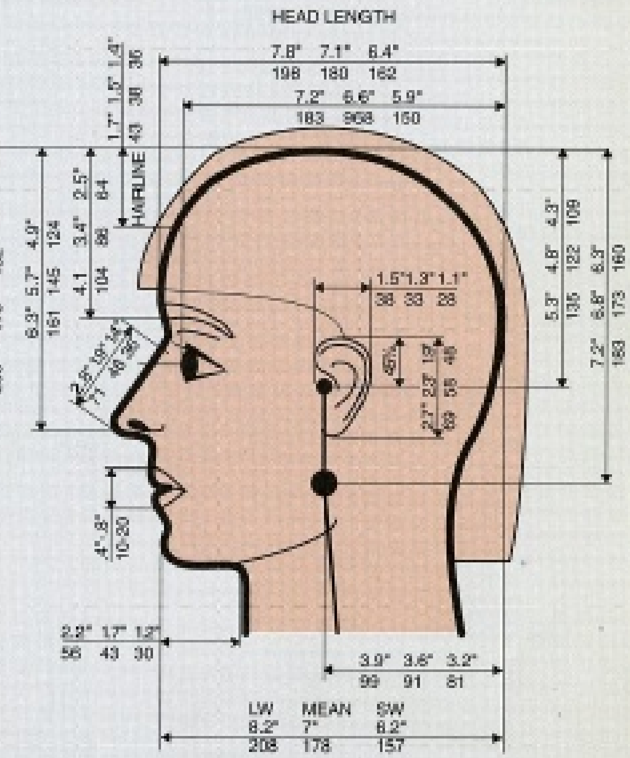
LW = 99 PERCENTILE WOMAN
SW = 1 PERCENTILE WOMAN











Measurement can vary depending on posture. Height varies between a straight or rigid posture as much as 0.2 to 0.8" (5 to 20 mm). There is a loss in height due to relaxing into a slumped posture.

Table of Possible Slumps

Posture	Men	Women
Standing	1.2" (30 mm)	1" (25 mm)
Sitting	0.3-2.6" (7.6-66 mm)	0.3-2" (7.6-51 mm)

There are height and weight variations with age. Stature increases to age 25, and it decreases from age 30 to 60.

Body weight increases through age 60. The greatest weight increase occurs between 30 and 40 years of age.

Chest and abdominal circumference also increase through age 60. Nutrition can vary girths and circumferences.

Strength decreases after 30 years of age.

THE LINK SYSTEM

For the visualization of the man-machine relationship, engineering principles can be applied in place of the complicated bone structure. Complex bone systems have been simplified by substituting single straight-line links. For example, the thigh bone is L-shaped. When changed to a straight line from pivot point to pivot point, its performance is the same, and it is easier to comprehend.

All bones are simplified in this manner. The pelvic bone is a large mass and is equated with a triangular link that is also a rigid unit performing the same function. The spinal column, consisting of 25 separate bones, is simplified to a few links, one for the thoracic (chest) area, one for the lumbar (hollow of the back) area, and one for the pelvic area. If more links and pivot points are added, the system can become much more complex and difficult to use in mechanical analysis. Pivot points are assumed to be simple in operation, although some body joints, such as the shoulder pivot, hip pivot, and spine, are complex.

The link system can be further enhanced by showing the maximum range of travel and the comfort range with this. Determination of link lengths is difficult since pivot points are not measurable on the body. The use of x-rays and skeleton analysis has helped in the past, but improved data collecting techniques are still needed. One thing is certain: a link length must be constant for all anthropometric data. One good check is the span measurement, which must equal (for example) two arm lengths plus shoulder pivot to shoulder pivot; the arm links must also fit shoulder-to-elbow and elbow-to-fingertip measurements.

Data on the charts and template details are for full percentiles on the critical dimensions. For example, the following dimensions of the 99 percentile man are 99 percentile measurements:

Stature

Shoulder height

Shoulder to elbow

Elbow to fingertip

Buttock to knee

Knee to floor (without shoes)

Abdominal depth

Sitting height

A product design should accommodate all users between the 99 percentile man and the 1 percentile woman. The mean figures can be used in illustrations for normal applications. Data from the following anthropometric souces were used to prepare the charts depicting adult males and females: *Humanscale 1/2/3*, 1974; NASA, 1978; and U.S. Department of Health, Education, and Welfare, 1966 and 1979.

Complete data are also included for infants to youths 18 years of age. This information was adapted from SAE, 1975 and 1977.

The Dynamic Body Versus the Static Body

The rove and reach of shoulder pivots may be extended by extending the shoulder, rotating the trunk, and/or bending the trunk (without safety belt). The arcs these movements describe in space are not spherical and are complex.

Controls on a panel at a distance beyond the reach of the fingertips can be reached by extending the shoulder until the thumb touches the panel.

Reach Additions with Arm Horizontal

Below are listed gains in reach by men and women bending forward, to the side, and 45° in between. Numbers are approximate, in inches and millimeters.

Men

Direction	Extend Shoulder	Rotate Trunk	Bend Trunk	Total
Forward	4 (100)	2 (50)	10 (250)	16 (405)
45°	3 (75)	1 (25)	8 (200)	12 (305)
Side	2 (50)	0	6 (150)	8 (200)

Women

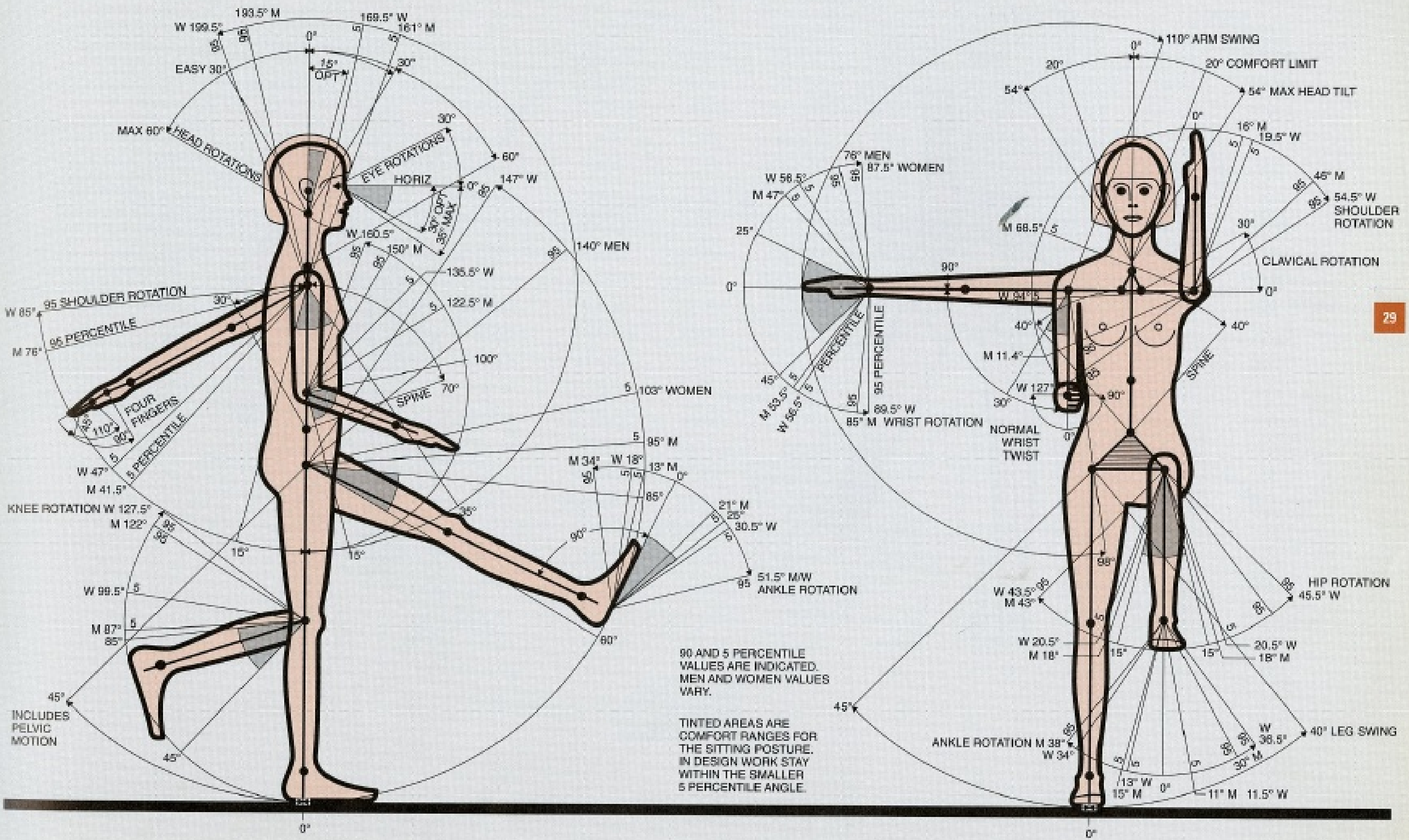
Direction	Extend Shoulder	Rotate Trunk	Bend Trunk	Total
Forward	4 (100)	1.8 (45)	8.2 (205)	14 (355)
45°	3 (75)	0.9 (20)	6.4 (160)	10.3 (260)
Side	2 (50)	0	5.6 (140)	7.6 (190)

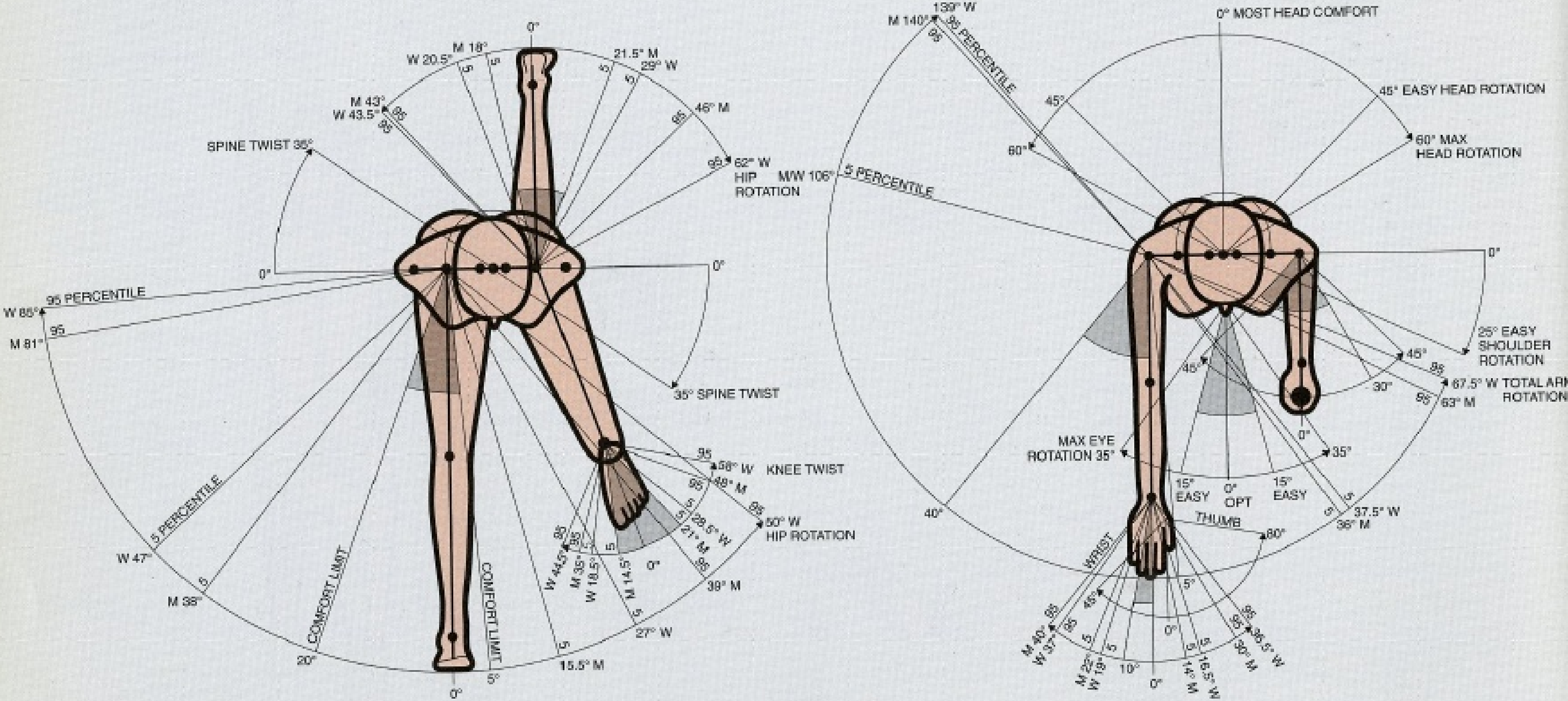
Angles other than horizontal ones must be computed or solved graphically.

Designs intended to confine the operator or otherwise encompass the entire body—such as driver compartments, cockpits, etc.—can be drawn in orthographic views (side, front, and plan) on the board or computer screen as a guide to constructing a full-size model or mock-up. Three-dimensional manikins or dummies can be used to analyze space requirements. Some dummies have correct weights for each body component and can be used in dynamic tests for safety.

The use of live models is recommended to check out mock-ups. People corresponding to the largest and smallest operators of the equipment should be chosen. Typically, many new factors will be revealed as a result of this evaluation.

The figures in the Measure of Woman diagrams also indicate frontal clearance required at various stages of pregnancy, the maximum being indicated on the large woman and the minimum on the small woman. However, this is not always realistic; the small woman may have larger dimensions or a higher hip pivot-to-seat distance than the 1 percentile shown. These dimensions do not necessarily correlate with stature.


193.5° M
W 199.5°
169.5° W
161° M
0°
EASY 30°
15° OPT
30°
MAX 60°
HEAD ROTATIONS
EYE ROTATIONS
30°
HORIZ
0°
30° OPT
35° MAX
60°
147° W
W 160.5°
150° M
140° MEN
135.5° W
122.5° M
95 SHOULDER ROTATION
30°
W 85°
95 PERCENTILE
M 76°
100°
SPINE
70°
FOUR FINGERS
110°
90°
5 PERCENTILE
103° WOMEN
95° M
W 47°
M 41.5°
M 34°
W 18°
13° M
0°
85°
KNEE ROTATION W 127.5°
M 122°
35°
21° M
25°
30.5° W
15°
15°
90°
51.5° M/W
ANKLE ROTATION
W 99.5°
M 87°
85°
60°
45°
INCLUDES PELVIC MOTION
45°
0°
90 AND 5 PERCENTILE VALUES ARE INDICATED. MEN AND WOMEN VALUES VARY.
TINTED AREAS ARE COMFORT RANGES FOR THE SITTING POSTURE. IN DESIGN WORK STAY WITHIN THE SMALLER 5 PERCENTILE ANGLE.
0°
110° ARM SWING
20°
20° COMFORT LIMIT
54°
54° MAX HEAD TILT
0°
16° M
19.5° W
76° MEN
87.5° WOMEN
W 58.5°
M 47°
46° M
54.5° W
SHOULDER ROTATION
25°
M 68.5°
30°
CLAVICAL ROTATION
90°
0°
0°
W 94°
40°
40°
M 11.4°
SPINE
PERCENTILE
95 PERCENTILE
45°
M 53.5°
W 56.5°
W 127°
30°
90°
89.5° W
85° M WRIST ROTATION
NORMAL WRIST TWIST
0°
98°
W 43.5°
M 43°
HIP ROTATION
45.5° W
W 20.5°
M 18°
15°
15°
20.5° W
18° M
45°
ANKLE ROTATION M 38°
W 34°
W 38.5°
40° LEG SWING
30° M
13° W
15° M
0°
11° M
11.5° W
0°
29



TINTED AREAS ARE COMFORT RANGES. IN DESIGN WORK STAY WITHIN THE SMALLER 5 PERCENTILE ANGLE.

CLOTHING CORRECTIONS

Clothing must be taken into consideration when designing compartments and seating arrangements. If a condition exists that must accommodate the 99 percentile man and the 1 percentile woman, add the heaviest clothing required to the large man and add the lightest clothing to the small woman. Hats are important; include a 2" clearance between the highest hat and the ceiling to allow for rising and falling during walking. Shoe heights are important to determine ceiling clearance and seat heights. Spacing between arm rests will depend on the sitting buttock width, with the bulkiest clothing anticipated.

Gloves affect space requirements. A bare hand opening of 1.5 x 3.8" (38 x 97 mm) has to be increased, for heavy gloves, to 2 x 4.5" (51 x 114 mm). Gloved hands are not as sensitive. A push-button travel of 0.1" (3 mm) must be increased to 0.3" (8 mm) for heavy gloves.

The tables of data that follow show the increase required on each side for various types of clothing. The first table is for civilian increases for men and women, and the second table is for military men. Values are approximate, for styles of clothing change. Military and safety helmets are about 12 x 10.25" (305 x 260 mm).

Clothing Increases for Men and Women (Approximate, in Inches and Millimeters)

	Men		Women		Military Men		Arctic	
	Street Clothes	Winter Clothes	Street Clothes	Winter Clothes	Army Light	Army Heavy	Flying Heavy	Parka & Boots
Stature	1.2 (30)	3.2 (80)	1.2 (30)	4 (100)	2.65 (67)	2.65 (67)	3 (75)	4.3 (110)
Sitting hgt	0.1 (2.5)	2.3 (60)	0.1 (2.5)	2.7 (70)	1.39 (35)	1.61 (41)	1.61 (41)	NA
Head hgt	Bare	2 (50)	Bare	3 (75)	1.4 (36)	1.4 (36)	1.35 (35)	NA
Head w	Bare	2 (50)	Bare	3 (75)	2.8 (71)	2.8 (71)	2.8 (71)	NA
Head lg	Bare	2 (50)	Bare	3 (75)	3.5 (89)	3.5 (89)	3.5 (89)	NA
Shoulder w	0.5 (13)	2 (50)	0.25 (6.4)	1 (25)	0.24 (61)	1.52 (39)	1.52 (39)	4.7 (120)
Shoulder hgt	0.6 (15)	2 (50)	0.35 (9)	1.25 (32)	0.24 (61)	1.52 (39)	0.92 (23)	NA
Hip w sit	0.5 (13)	2 (50)	0.25 (6.4)	1 (25)	0.56 (14.2)	1.4 (36)	1.44 (37)	5.2 (132)
Abdomen	0.9 (23)	1.7 (43)	0.3 (7.6)	1 (25)	1.2 (30)	2.5 (65)	1.4 (36)	NA
2 Elbow w	0.8 (20.3)	4 (100)	0.4 (10)	2 (50)	1 (25)	2.1 (55)	1.84 (47)	5.9 (150)
Elbow lg	0.4 (10)	2 (50)	0.2 (5)	1 (25)	0.56 (14.2)	1.84 (48)	0.94 (25)	NA
Hand w	Bare	0.4 (10)	Bare	0.4 (10)	Bare	0.3 (7.6)	0.4 (10)	1.2 (30)
Hand lg	Bare	0.2 (5)	Bare	0.2 (5)	Bare	0.2 (5)	0.3 (7.6)	0.6 (16)
Hand thk	Bare	0.5 (12.7)	Bare	0.5 (12.7)	Bare	0.4 (10)	0.4 (10)	0.6 (16)
Thigh clear	0.5 (12.7)	1 (25)	0.3 (7.6)	0.8 (20.3)	0.3 (7.6)	0.4 (10)	2 (50)	NA
2 knee w	0.3 (7.6)	0.4 (10)	0.1 (2.5)	0.1 (2.5)	0.5 (12.7)	1.7 (43)	0.72 (18)	NA
Knee to fl	1.5 (38)	1.6 (40)	1.3 (33)	1.3 (33)	1.32 (35)	1.44 (37)	1.44 (37)	NA
Knee to back	0.8 (20)	3 (75)	0.6 (15)	1.8 (45)	0.2 (5)	0.7 (18)	0.54 (14)	1 (25)
Foot w	0.5 (12.7)	1 (25)	0.3 (7.6)	0.5 (12.7)	0.2 (5)	0.2 (5)	0.2 (5)	NA
Foot lg	1.3 (33)	1.5 (38)	0.5 (12.7)	1.5 (38)	1.6 (40)	1.6 (40)	1.6 (40)	NA
Heel hgt	1.2 (30)	1.5 (38)	1.2 (30)	1.5 (38)	1.3 (33)	1.3 (33)	1.3 (33)	1.3 (33)
Wt lb (kg)	5 (2.3)	10.0 (4.5)	3.5 (1.6)	7 (3.2)	9.4 (4.3)	11.8 (5.4)	20. (9)	NA

(Source: Humanscale 1/2/3, *1974.)*

WORK AND PLAY STATIONS FOR CHILDREN

Work and Play Stations for Combined 50 Percentile Male and Female Children, in Inches and Millimeters.

	Sitting				Standing			
Age	Chair Height	Elbow Height	Desk Height	Desktop Reach	Chair Height	Elbow Height	Desk Height	Desktop Reach
3	8 (205)	13.7 (350)	15 (380)	12 (305)	37 (940)	21 (535)	20 (510)	14 (355)
4	9 (230)	14.6 (370)	16 (405)	14 (355)	40 (1020)	23 (585)	22 (560)	15 (380)
5	10 (255)	15.7 (400)	17 (430)	15 (380)	43 (1095)	24.5 (622)	23 (585)	17 (430)
6	11 (280)	17.2 (440)	18 (460)	16 (405)	45 (1145)	26 (660)	24 (610)	18 (460)
7	11.5 (290)	18.1 (460)	19 (480)	18 (460)	48 (1220)	28.5 (725)	26 (660)	20 (510)
8	12 (305)	18.8 (480)	20 (510)	19 (480)	50 (1270)	30 (760)	27 (685)	21 (535)
9	13 (330)	19.7 (500)	21 (535)	20 (510)	52.5 (1330)	31 (790)	28 (710)	22 (560)
10	13.5 (345)	20.2 (515)	22 (560)	21 (535)	54 (1375)	32.5 (825)	29 (740)	23 (585)
11	14 (355)	20.8 (530)	23 (585)	22 (560)	56.5 (1435)	34 (865)	30 (760)	24 (610)
12	15 (380)	21.4 (545)	24 (610)	23 (585)	59 (1495)	35 (890)	31 (790)	25 (635)
13	15 (380)	22.1 (560)	25 (635)	24 (610)	61 (1550)	36.5 (925)	32 (815)	26 (660)
14	16 (405)	23 (585)	26 (660)	24 (610)	63 (1600)	37.5 (950)	33 (840)	27 (685
15	16 (405)	23.6 (600)	26.5 (675)	24 (610)	65 (1650)	38.5 (980)	34 (865)	28 (710)
16	16.5 (420)	24.4 (620)	27.5 (700)	24 (610)	66.5 (1690)	40 (1015)	35 (890)	29 (735)
17	16.5 (420)	24.9 (630)	28 (710)	24 (610)	66.5 (1690)	40 (1015)	35 (890)	29 (735)
18	16.5 (420)	24.9 (630)	28 (710)	24 (610)	68 (1725)	41 (1040)	36 (915)	30 (760)

(Source: SAE, 1977.)

Standing height includes shoes and a slight slump in posture.

Maximum elbow rise at table is 3" (76 mm).

Maximum distance from chair to desktop is 12" (305 mm).

It is difficult to accommodate all children in one age bracket; the 5 percentile might prefer a chair 1" (25.4 mm) lower and the 95 percentile might prefer a chair 1" higher.

THE ELDERLY

There are currently more Americans over 65 than there are teenagers. Data for a distinct population of the elderly exist for people of the ages 65 to 79. Data on ages 80 to 90 are not available.

The large elderly man has lost 5% of his height, compared to when he was 20 years old, because of several factors. The elderly man no longer has the growth advantage of 0.4" (10 mm) per decade, and his cartilage has shrunk, mostly throughout the spine. Also, posture among the aged has a more slumped character.

The small elderly woman has lost 6% of her height for the same reasons as the elderly man.

Other factors concerning the elderly include the following:

- Hand strength is reduced about 16-40%.
- Arm strength is reduced about 50%.
- Leg strength is reduced about 50%.
- Air intake is reduced about 35%.
- Most body breadth decreases with increasing age.
- Nose and ears increase in width and length.
- Weight can increase 4.4 lb (2 kg) every 10 years.

One-third of the total working population suffers from poorly corrected vision. This can be assumed to affect the elderly, in whom visual acuity will also have deteriorated as a result of the aging process.

AGE	%
20	100
40	90
60	74
80	47

(Source: Woodson, 1981.)

The eye focuses more slowly with aging. Moreover, the ability to perceive color diminishes with age because of the yellowing of the lens in the eye. It is consequently more difficult to distinguish greens, blues, and violets. (From *Color News*, October 30, 1989.)

Note the following also:

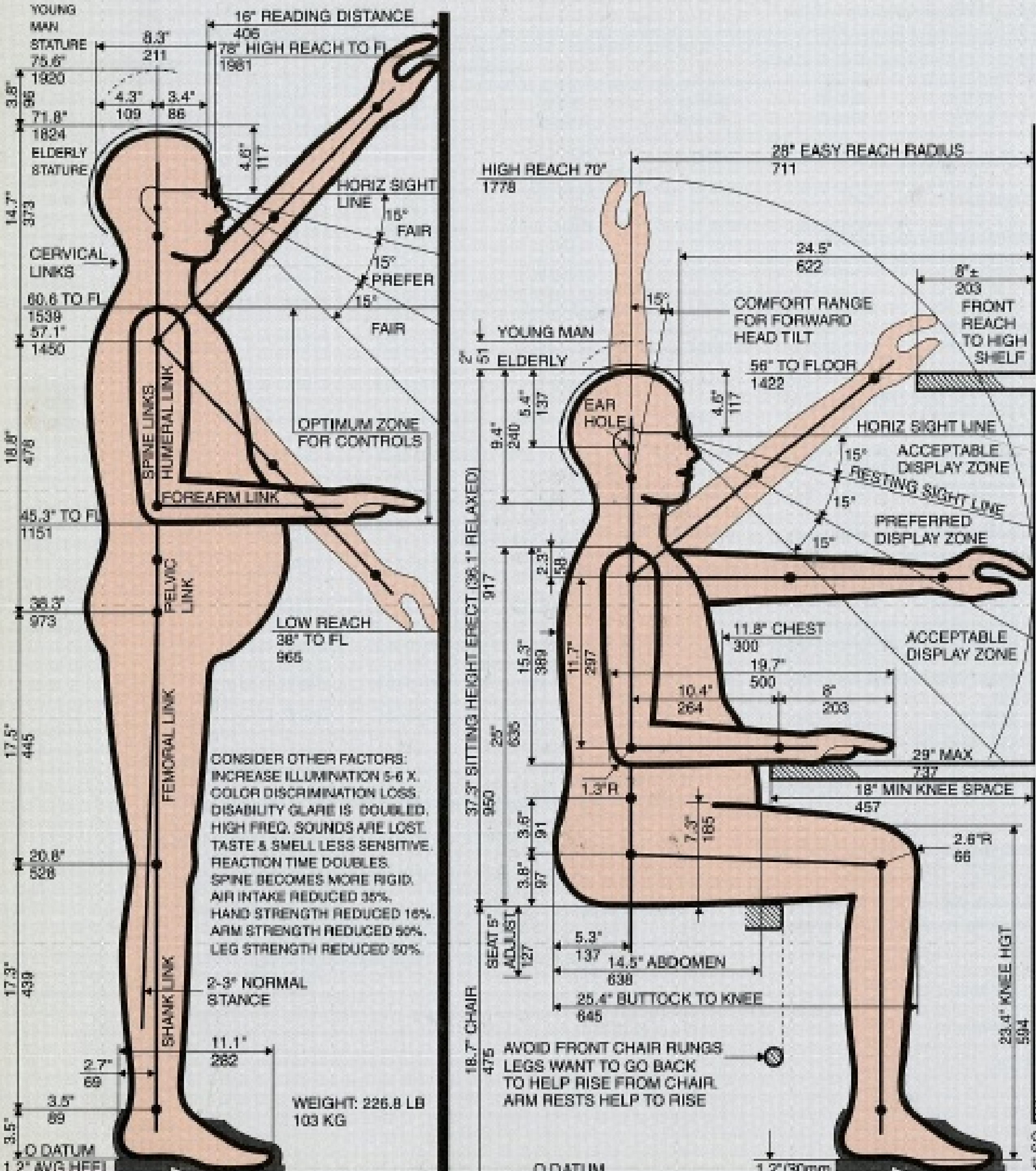
- The eye's reaction time doubles with aging.
- Disability glare doubles with aging.
- A 40-year-old requires 2 times the light a 20-year-old requires. A 60-year-old requires 5 or 6 times the light a 20-year-old requires.
- Older people need larger visual details.
- Increase illumination by about 20%.
- In hearing, high-frequency sounds are lost with aging; of course, hearing-aid correction is possible.
- Taste and smell become less sensitive with age. The elderly tend to use more salt, pepper, and strong flavors.

Design Considerations

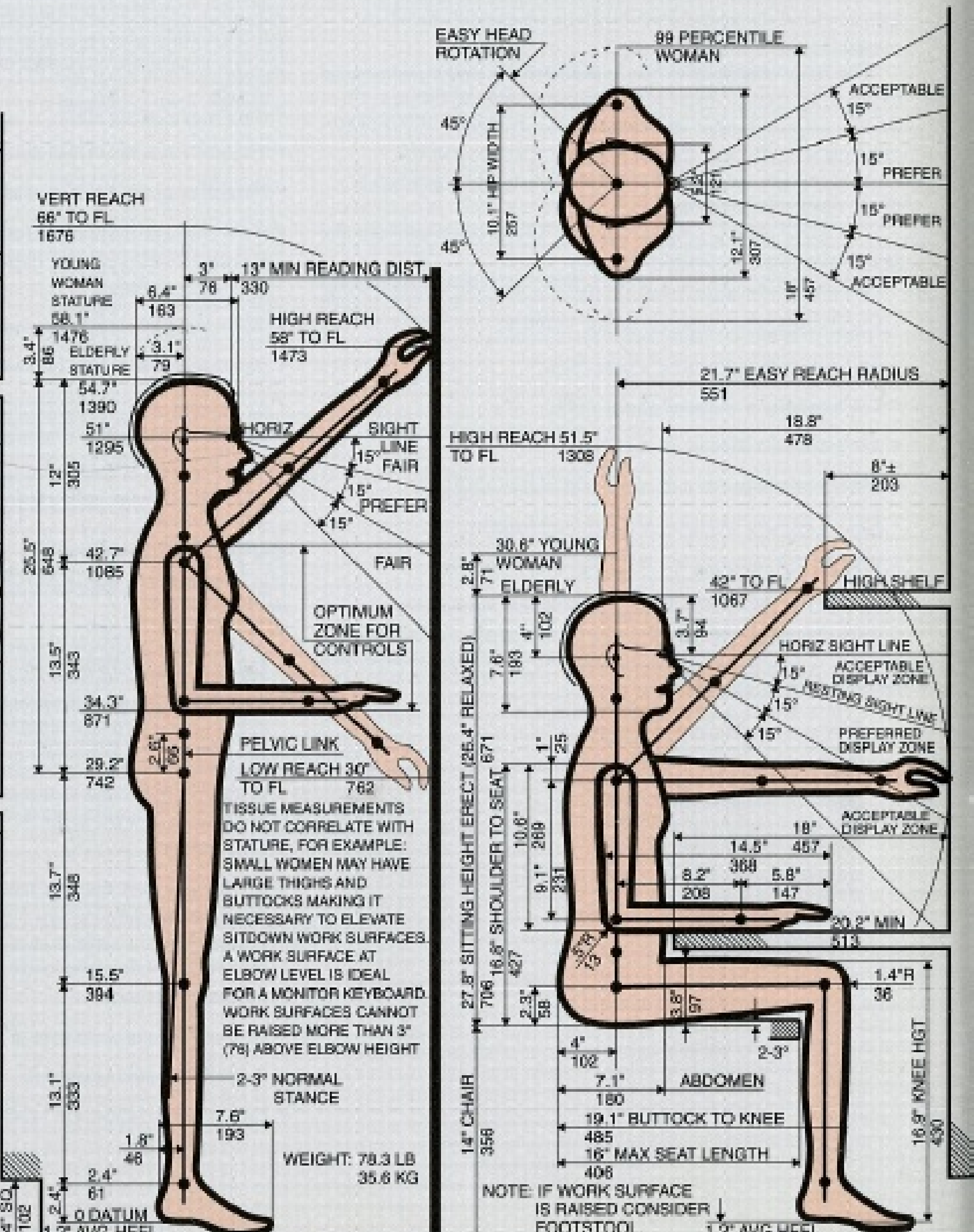
It is important to remember the following when designing or the elderly:

- Avoid front rungs on chairs for the elderly, because their legs move back to assist them in rising. Armrests also give them hand support for rising. It is very difficult for most elderly people to rise from a sofa.
- The height of seats and worktops must be adjustable or made to order. The worktop is best at elbow height for keyboards, but it can be 3" (76 mm) higher than the elbow for reading or writing.
- Remember that the small elderly woman is shown with all dimensions based on the 1 percentile. Since girths, buttocks, and thighs do not always correlate with a fixed stature, consideration must be given to these factors when designing furniture.
- Lower high-reach shelves 3" (76 mm).
- Raise low-reach shelves 3" (76 mm).
- Lower work tables 1.5" (38 mm)

ANTHROPOMETRY OF THE 99 PERCENTILE ELDERLY US MEN AGE 65-79



ANTHROPOMETRY OF THE 1 PERCENTILE ELDERLY US WOMEN AGE 65-79



DIFFERENTLY ABLED PEOPLE

The Americans with Disabilities Act, which was enacted in 1990 and became law in 1992, provides civil rights protection for individuals with disabilities in places of employment and in public accommodations, including state and local government services. Information presented here on differently abled people has been taken from the ADA.

Forty-three million Americans have one or more physical or mental disabilities, and this number is increasing as the population grows older. Before the ADA, these people were isolated or segregated and often discriminated against and put at a disadvantage socially, vocationally, economically, and educationally.

Now differently abled people, including those in wheelchairs, must be provided with equal goods, services, facilities, privileges, advantages, and accommodations. Individuals with a disability now must be accommodated in privately operated facilities, such as the following:

- Inns, hotels, motels, or other lodging places.
- Restaurants, bars, or other establishments serving food or drink.
- Motion-picture and other theaters, concert halls, stadiums, or other places of exhibition or entertainment.
- Auditoriums, lecture halls, convention centers, or other public gathering places.
- Shopping centers and sales or rental establishments, including bakeries, grocery stores, clothing stores, hardware stores, and video rental shops.
- Laundromats; dry cleaner shops; banks; barber shops; beauty salons; travel services; funeral parlors; gas stations; offices of accountants, insurance agents, or lawyers; pharmacies; professional offices of health-care providers; hospitals; and other service establishments.
- Terminals, depots, or other stations used for public transportation.
- Museums, libraries, galleries, and other places of public display or collection.
- Park, zoo, and amusement-park facilities, and other places of recreation.
- Nurseries and elementary, secondary, undergraduate, and post-graduate private schools and other places of education.
- Day-care and senior-citizen centers, homeless shelters, food banks, adoption agencies, or other social-service establishments.
- Gymnasiums, health spas, bowling alleys, golf-course facilites, and other places of exercise or recreation.

Publicly controlled agencies must also comply; this includes the following:

- Any state or local government facility.
- Any department, agency, special-purpose district, or other instrumentality of a state or states or local government.
- Any facility of the National Railroad Passenger Corporation or of any commuter authority.

Also, any means of public transportation by bus, rail, or any other conveyance (other than aircraft) that provides the public with general or special services (including charter services) on a regular and continuing basis is included.

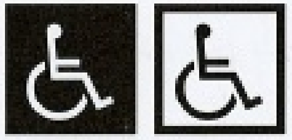
Exempted organizations include private clubs, religious organizations, and places of worship, unless some parts of these places are leased for public use.

There are four standard symbols of accessibility:

- The international symbol of wheelchair accessibility.
- The symbol of access for hearing loss.
- The international TDD symbol. TDD stands for Telecommunication Device for the Deaf.
- The symbol of handset volume control.

The law requires that no objects, including signs, shall protrude more than 4" (102 mm) from a wall or 12" (305 mm) from posts or pylons, in a horizontal zone between 27" (686 mm) from the floor to 80" (2032 mm) from the floor. Also, 80" is the minimum headroom in all corridors and similar spaces.

PROPORTIONS FOR INTERNATIONAL SYMBOL OF ACCESSIBILITY



DISPLAY CONDITIONS FOR INTERNATIONAL SYMBOL OF ACCESSIBILITY

INTERNATIONAL SYMBOL OF TELECOMMUNICATIONS DEVICE FOR THE DEAF (TDD)

INTERNATIONAL SYMBOL OF ACCESS FOR HEARING LOSS

SYMBOLS OF ACCESSIBILITY

The following list presents examples of steps to be taken to remove architectural barriers:

- Widen doorways, or install offset hinges to doors, to accommodate wheelchairs.
- Install accessible door hardware.
- Eliminate turnstiles or provide alternate, accessible pathways.
- Remove high-pile, low-density carpeting.
- Install ramps where there are only stairs.
- Make curb cuts in sidewalks and entrances.
- Rearrange furniture, vending machines, display racks, and other possible obstacles.
- Reposition telephones.
- Reposition shelves.
- Add raised markings on elevator control buttons.
- Install flashing alarm lights.
- Install vehicle hand controls.
- Designate accessible parking spaces for the differently abled.
- Install grab bars in toilet stalls.
- Rearrange toilet partitions to increase maneuvering space.
- Insulate lavatory pipes under sink to prevent burns.
- Install a raised toilet seat.
- Install full-length bathroom mirrors.
- Reposition paper-towel dispensers in bathrooms.
- Install a paper-cup dispenser to make it possible to drink at an inaccessible water fountain.

Wheelchairs

The following specifications serve as standards for wheelchair design:

Dimension	in	mm
Handle height	36	915
Armrest height	30	760
Lap height	27	685
Seat height	19	485
Toe height	8	205
Eye-level height	43–51	1090–1295
Overall width	26	660
Overall length	42	1065*
Footrest width	18	455

**Foot extension beyond this is 6" (150 mm); footrests may extend more for tall people.*

The floor space required for wheelchair clearance and movement has been established as follows:

- Minimum clear floor space: 30 x 48" (760 x 1219 mm).
- Clear floor space for forward approach into an alcove of 24" (610 mm) depth or less: 30 x 48" (760 x 1219 mm).
- Clear floor space for forward approach into an alcove more than 24" (610 mm) deep: 36 x 48" (915 x 1219 mm).
- Clear floor space for side approach into an alcove of 15" (380 mm) depth or less: 30 x 48" (760 x 1220 mm).
- Clear floor space for side approach into an alcove more than 15" (380 mm) deep: 30 x 60" (760 x 1525 mm).
- Preferred doorway clearance: 36" (915 mm). Minimum: 32" (815 mm).
- Minimum hall width: 36" (915 mm).
- Preferred hall width for two wheelchairs: 64" (1625 mm). Minimum: 60" (1525 mm).
- Turning space for a wheelchair: 60" (1525 mm) diameter.
- T-shaped space required for 180° turns: 36" (915 mm) width in each of the three corridors; 60" (1525 mm) minimum depth in each direction.

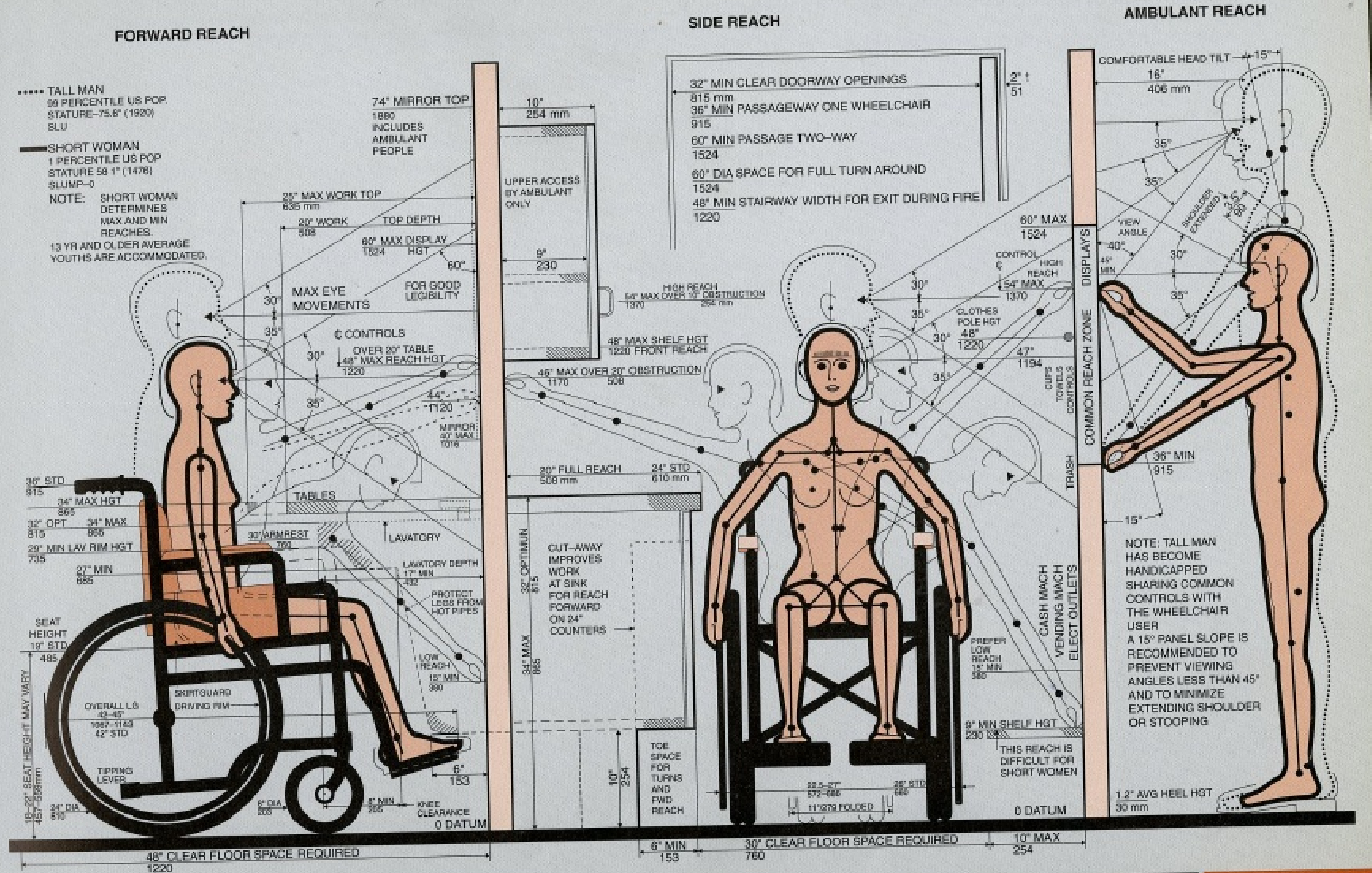
High and Low Reaches from a Wheelchair

- Forward approach (toes touching wall):

  High reach: 48" (1219 mm) maximum. Low reach: 15" (380 mm) minimum.
- Side reach, with 10" (255 mm) maximum distance between chair and wall:

  High reach: 54" (1370 mm) maximum. Low reach: 9" (230 mm) minimum; however, 15" (380 mm) minimum is preferable.
- Maximum side reach over a countertop of 24" (610 mm) depth and 34" (865 mm) maximum height:

  High reach: 46" (1170 mm).


FORWARD REACH
SIDE REACH
AMBULANT REACH
TALL MAN
99 PERCENTILE US POP.
SHORT WOMAN
1 PERCENTILE US POP
NOTE: SHORT WOMAN DETERMINES MAX AND MIN REACHES.
13 YR AND OLDER AVERAGE YOUTHS ARE ACCOMMODATED.
74" MIRROR TOP
1880
INCLUDES AMBULANT PEOPLE
10"
254 mm
UPPER ACCESS BY AMBULANT ONLY
25" MAX WORK TOP
635 mm
20" WORK TOP DEPTH
508
60" MAX DISPLAY HGT
1524
9"
230
MAX EYE MOVEMENTS
FOR GOOD LEGIBILITY
℄ CONTROLS
OVER 20" TABLE
48" MAX REACH HGT
1220
44"
1120
TABLES
LAVATORY
LAVATORY DEPTH
17" MIN
432
PROTECT LEGS FROM HOT PIPES
LOW REACH
15" MIN
380
36" STD
915
34" MAX HGT
865
32" OPT
815
34" MAX
865
29" MIN LAV RIM HGT
735
27" MIN
685
30" ARMREST
760
SEAT HEIGHT
19" STD
485
16–22" SEAT HEIGHT MAY VARY
SKIRTGUARD
DRIVING RIM
TIPPING LEVER
24" DIA
610
8" DIA
203
8" MIN
203
KNEE CLEARANCE
6"
153
0 DATUM
48" CLEAR FLOOR SPACE REQUIRED
1220
32" MIN CLEAR DOORWAY OPENINGS
815 mm
36" MIN PASSAGEWAY ONE WHEELCHAIR
915
60" MIN PASSAGE TWO-WAY
1524
60" DIA SPACE FOR FULL TURN AROUND
1524
48" MIN STAIRWAY WIDTH FOR EXIT DURING FIRE
1220
2"
51
HIGH REACH
54" MAX OVER 10" OBSTRUCTION
1370
254 mm
48" MAX SHELF HGT
1220 FRONT REACH
46" MAX OVER 20" OBSTRUCTION
1170
508
20" FULL REACH
508 mm
24" STD
610 mm
32" OPTIMUM
815
34" MAX
865
CUT-AWAY IMPROVES WORK AT SINK FOR REACH FORWARD ON 24" COUNTERS
10"
254
TOE SPACE FOR TURNS AND FWD REACH
6" MIN
153
30" CLEAR FLOOR SPACE REQUIRED
760
10" MAX
254
60" MAX
1524
CONTROL ℄
HIGH REACH
54" MAX
1370
CLOTHES POLE HGT
48"
1220
47"
1194
CUPS TOWELS COMMON CONTROLS
DISPLAYS
COMMON REACH ZONE
TRASH
CASH MACH
VENDING MACH
ELECT OUTLETS
PREFER LOW REACH
9" MIN SHELF HGT
230
THIS REACH IS DIFFICULT FOR SHORT WOMEN
11" 279 FOLDED
0 DATUM
COMFORTABLE HEAD TILT
15°
16"
406 mm
VIEW ANGLE
40°
45° MIN
SHOULDER EXTENDED
36" MIN
915
15°
NOTE: TALL MAN HAS BECOME HANDICAPPED SHARING COMMON CONTROLS WITH THE WHEELCHAIR USER
A 15° PANEL SLOPE IS RECOMMENDED TO PREVENT VIEWING ANGLES LESS THAN 45° AND TO MINIMIZE EXTENDING SHOULDER OR STOOPING
1.2" AVG HEEL HGT
30 mm

Curb Cuts, Threshold Levels, and Ramps for Wheelchairs

An accessible route does not include steps, including escalators. For the requisite alternatives, consult the diagram for ramps for the differently abled.

- Curb cuts should have a 36" (915 mm) minimum width. The slope should not exceed 1:20 (1 high to 20 deep), and the flared sides should slope 1:10. If the uncut balance of the sidewalk is less than 48" (1219 mm), the flared sides should not slope more than 1:12.
- A square step of 0.25" (6.5 mm) maximum is acceptable, but if the change in level is 0.25–0.50" (6.5–13 mm), a slope of 1:2 is required.
- A single ramp should have a slope of 1:12 to 1:16 for a 30-ft run (9 m) and a maximum slope of 1:16 to 1:20 for a 40-ft run (12 m).
- The minimum ramp width, including the landing, is 36" (915 mm).
- The landing length should be a minimum of 60" (1525 mm).
- The landing width that must accommodate a change in direction should measure 60 x 60" (1525 x 1525 mm).
- Range of handrail heights: 34–38" (865–965 mm).
- If the handrails are not continuous, extend them by 12" (305 mm) at each end parallel to the floor.
- Handrail size: 1.25–1.50" (32–38 mm) diameter. To prevent the hand from falling behind the railing and getting trapped, provide a 1.5" (38 mm) clearance to the wall.
- Handrails must not rotate.

Floor Surfaces for Wheelchair Users

Wheelchairs roll easier on hard, stable, regular surfaces. Soft, loose surfaces, such as sand, gravel, and wet clay, and irregular surfaces, such as shag carpets, impede travel.

Prefer a static coefficient of 0.6 for already-accessible routes and 0.8 for ramp installations.

Wheelchair Emergency Exits

Along with an exit path for ambulatory persons, provide a 48" (1219 mm) clearance between handrails on any emergency exit staircase to permit a person in a wheelchair to be carried.

Lavatories for Wheelchair Users

Provide for a basin height of 34" (865 mm) maximum when designing lavatories for wheelchair users.

- Lavatory projection from wall: 17" (430 mm) minimum.
- Rim height: 29" (735 mm) maximum.
- Leg clearance under the basin: 27" (685 mm) minimum.
- Pipe enclosure to protect user from burns: 9" (230 mm) minimum clearance to the floor. Projection of pipe from wall at bottom: 6" (150 mm) maximum. Knee clearance from the front edge of the lavatory: 8" (205 mm) deep minimum.
- Mirror height: Floor to bottom edge: 40" (1015 mm) maximum; floor to top edge: 74" (1880 mm). A full-length mirror is also desirable in an additional area to accommodate all adults and children.
- Provide a full 30 x 48" (760 x 1219 mm) floor space in front of the wall under the basin.

Drinking Fountains for Wheelchair Users

The spout height, from outlet to floor should be 36" (915 mm) maximum.

- Knee clearance: 27" (685 mm) minimum.
- Pipe enclosure: See lavatory specifications, above.
- Floor area for side and forward approaches: provide a 30 x 48" (760 x 1219 mm) space.

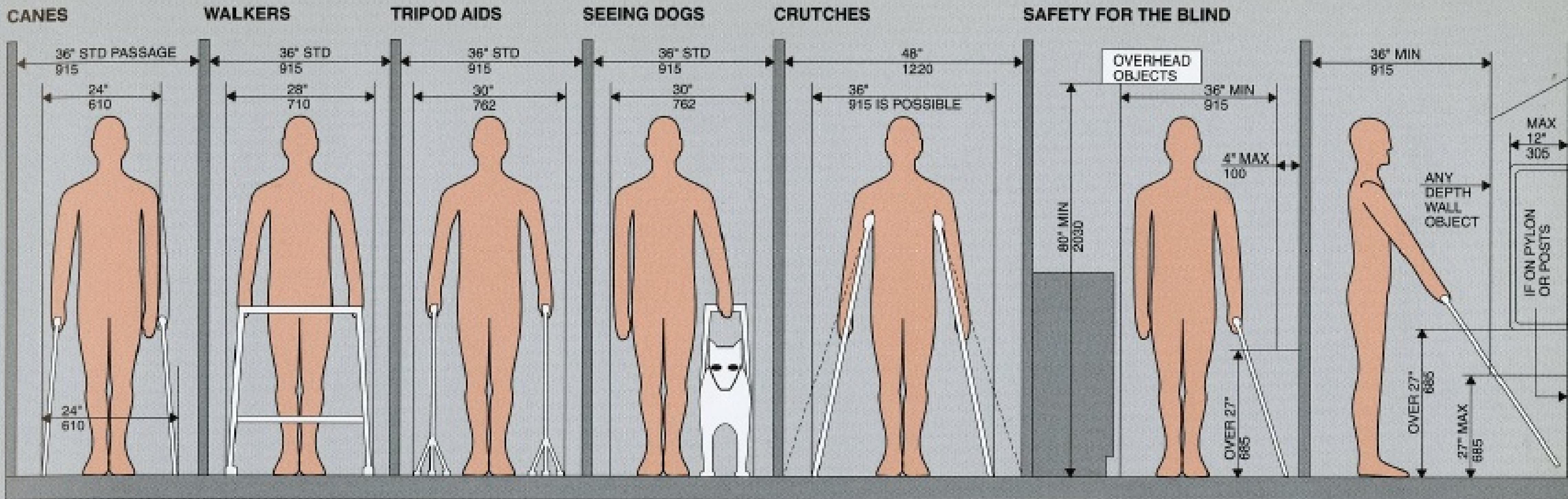
Urinals and Toilets for Wheelchair Users

Consider the following measurements when designing toilets and urinals:

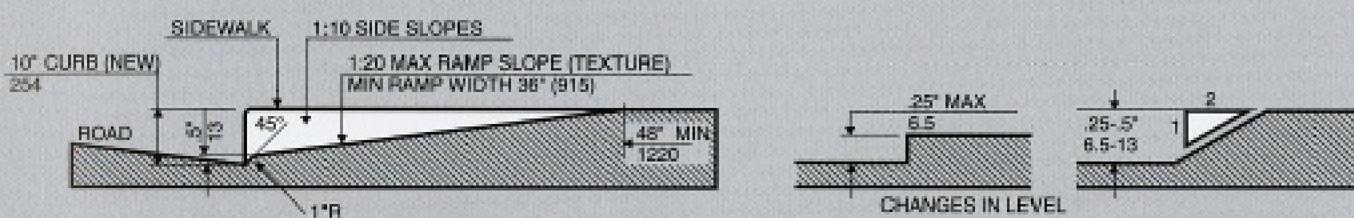
- Urinal rim height: 17" max (430 mm) above floor. The rim should be elongated.
- A toilet seat height of 18" (455 mm) can be used by all persons.
- Distance to side wall: 18" (455 mm) minimum.
- Grab bars: 1.25–1.50" (32–38 mm) diameter.
- Grab-bar mounting height: 33–36" (840–915 mm).
- Grab-bar length at back of toilet: 36" (915 mm).
- Grab-bar length on side wall: 42" (1065 mm) minimum, mounted 12" (305 mm) from the back wall; in the case of a 36" (915 mm) stall, use the same measurement, but with bars on both sides and no bar on the back wall.
- Paper roll height to center line: 19" (485 mm) minimum and mounted not more than 36" (915 mm) from the back wall.

Telephone Booths for Wheelchair Users

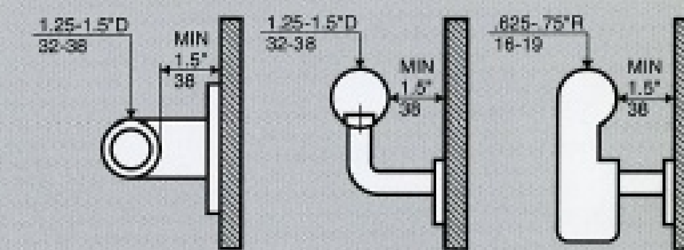
- Shelf: 28" (710 mm) and 18" (455 mm) deep.
- Knee clearance: 27" (685 mm) minimum.
- Entry width between side walls: 36" (915 mm). Side walls may be of any depth.



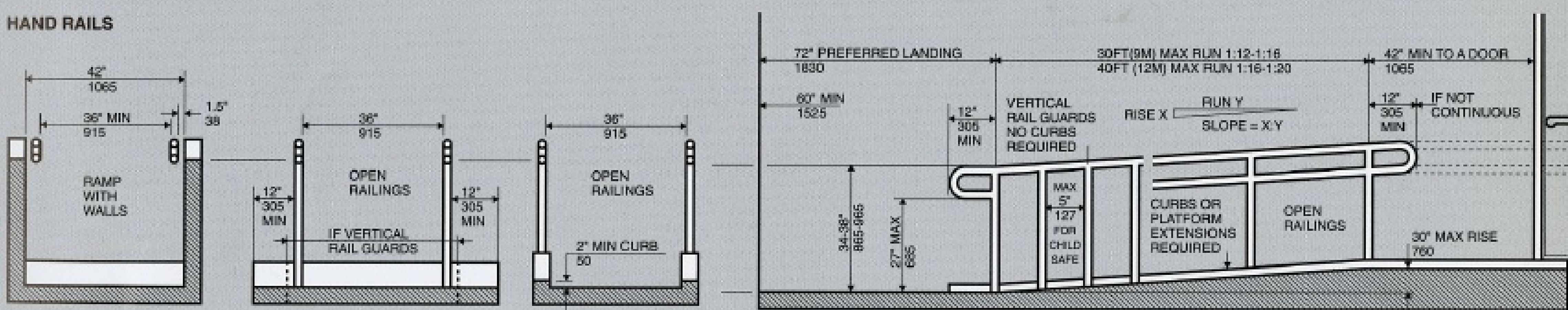
RAMPS FOR THE DIFFERENTLY ABLED



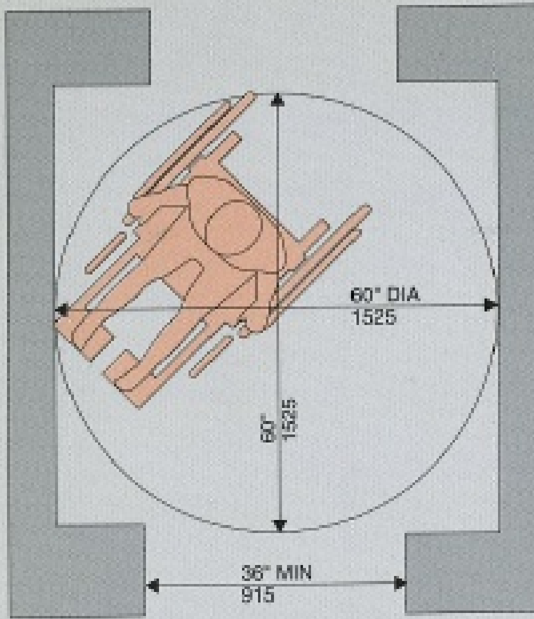
GRAB BAR



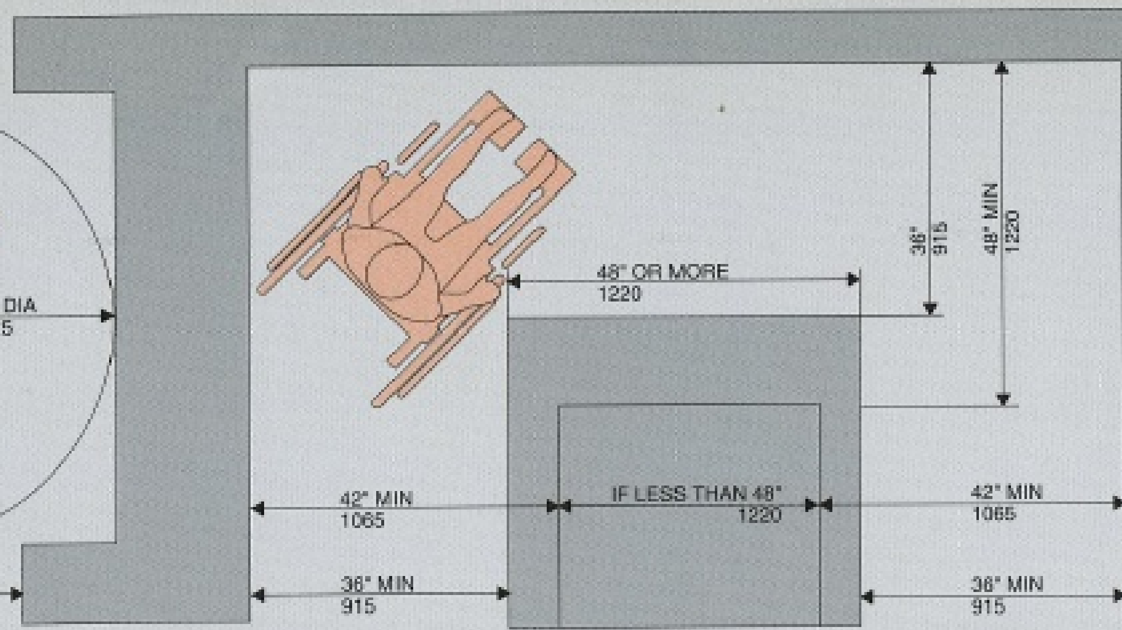
HAND RAILS



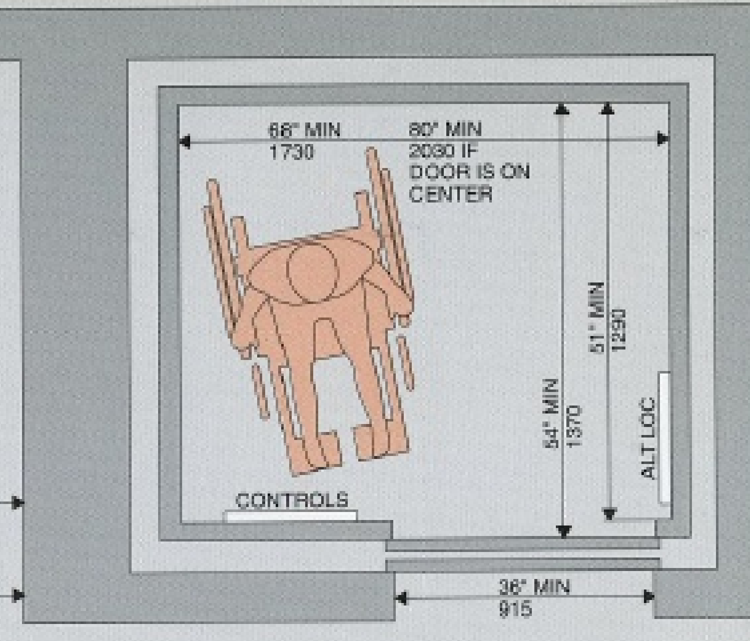
360° TURNS



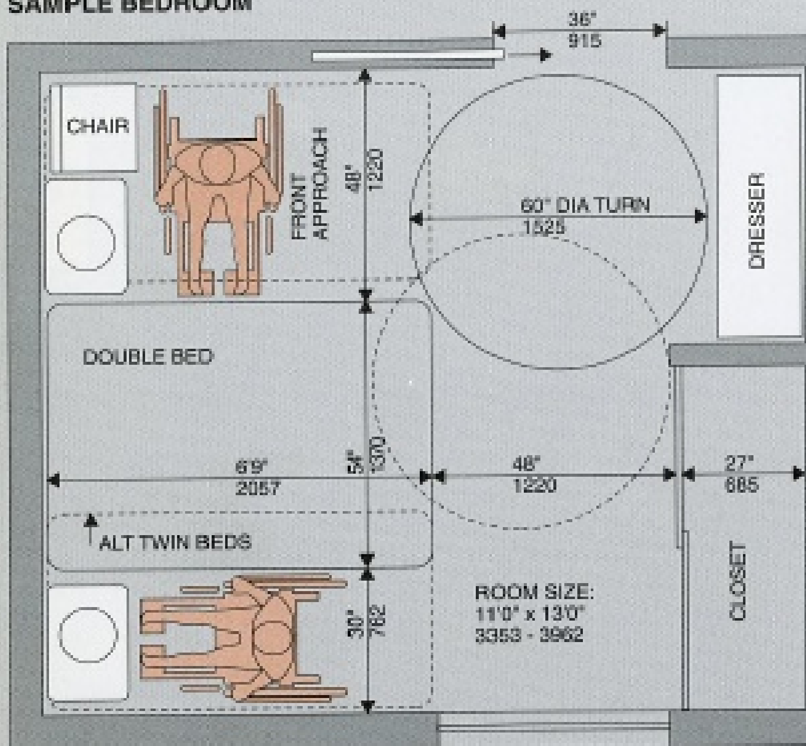
90° TURNS



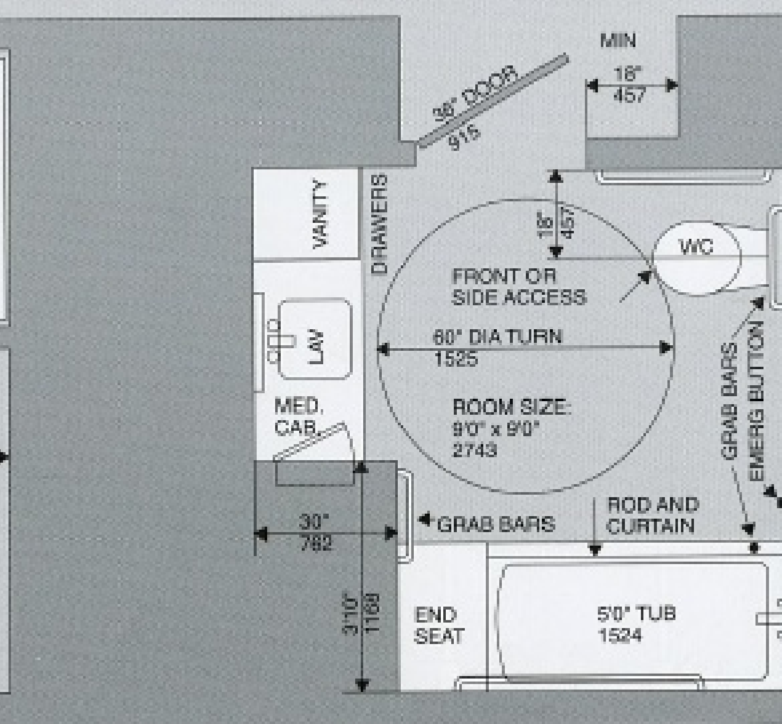
ELEVATOR CAR



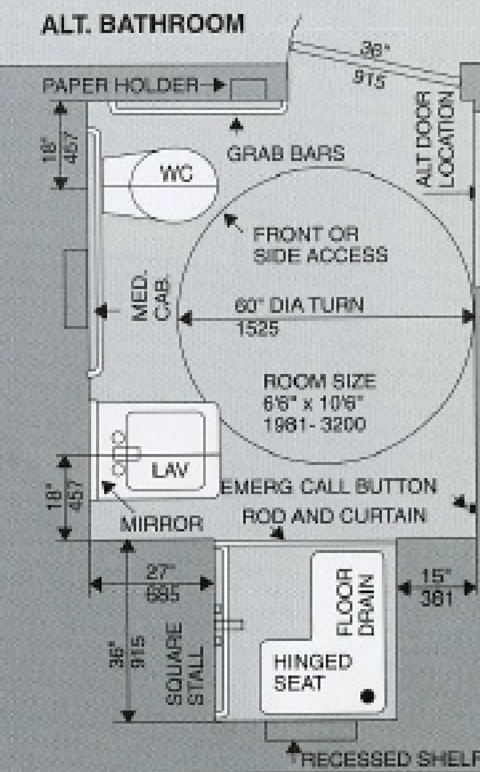
SAMPLE BEDROOM



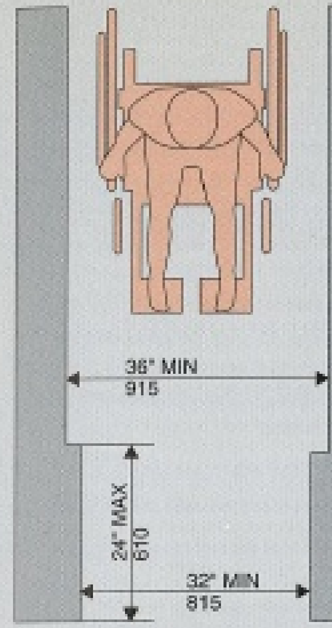
SAMPLE BATHROOM



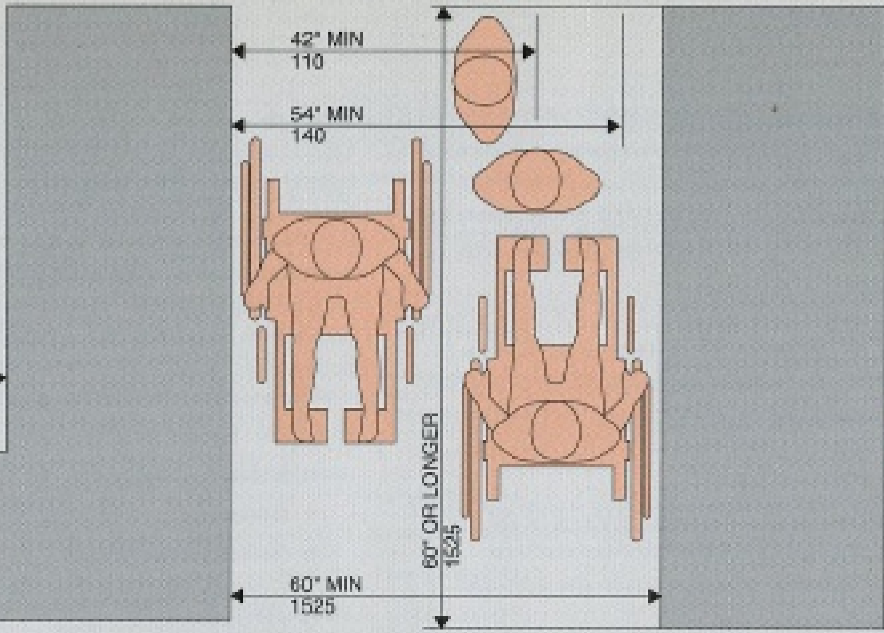
ALT. BATHROOM



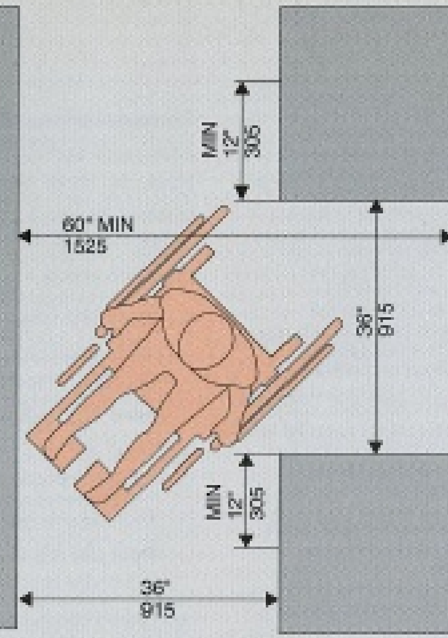
PASSAGE



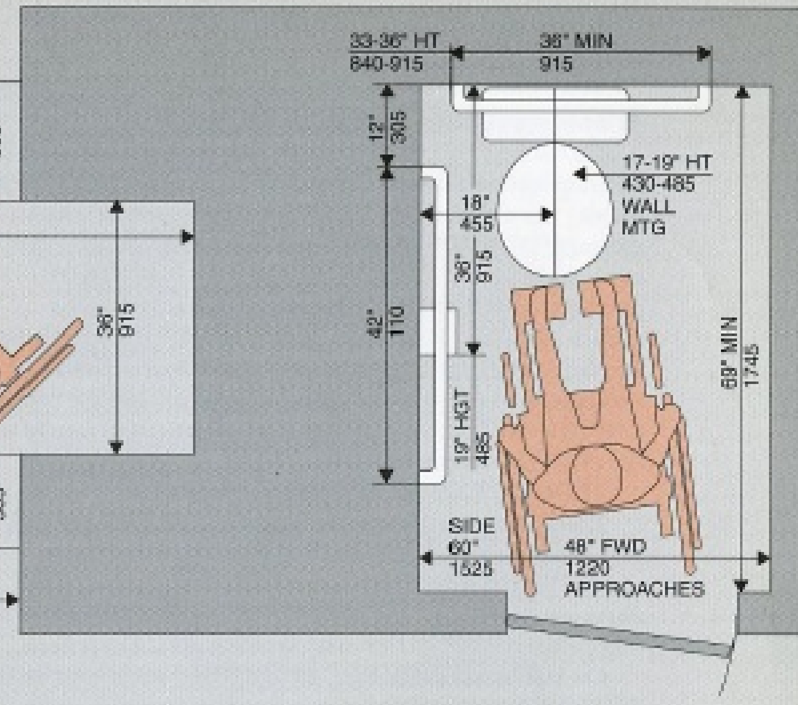
2-WAY PASSAGES



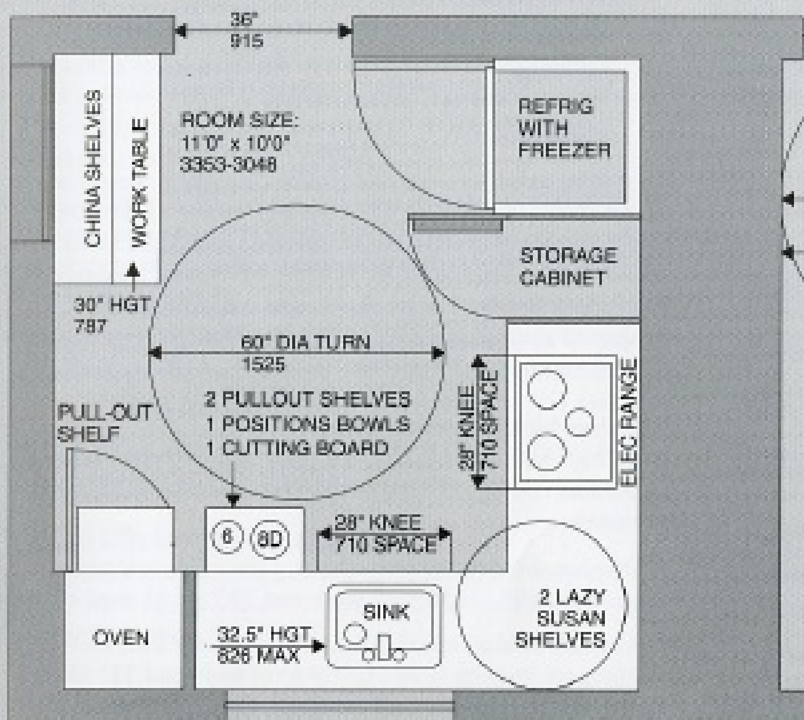
'T' OR 180° TURNS



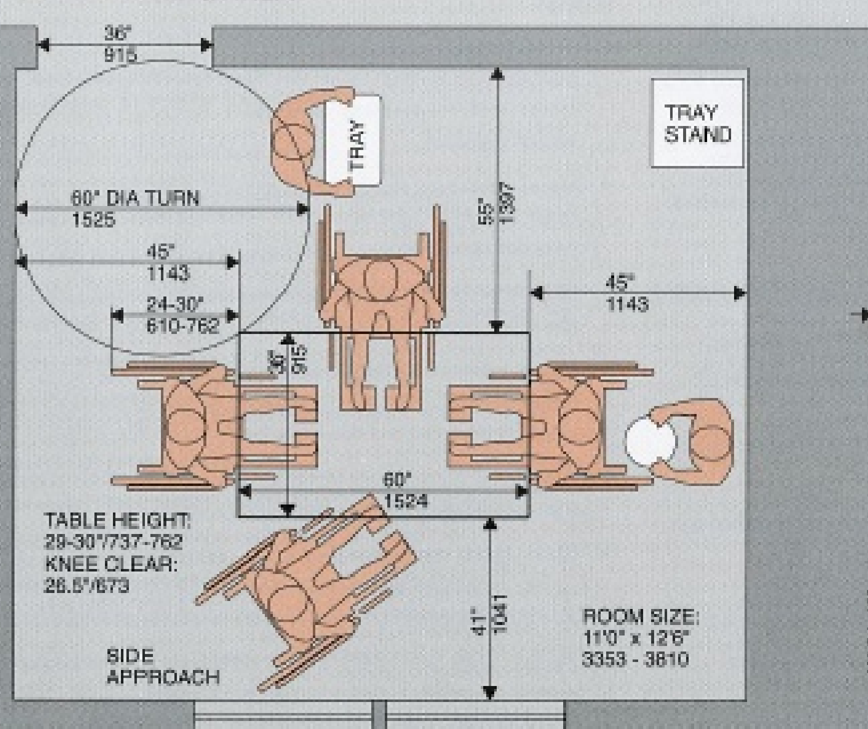
PUBLIC TOILET



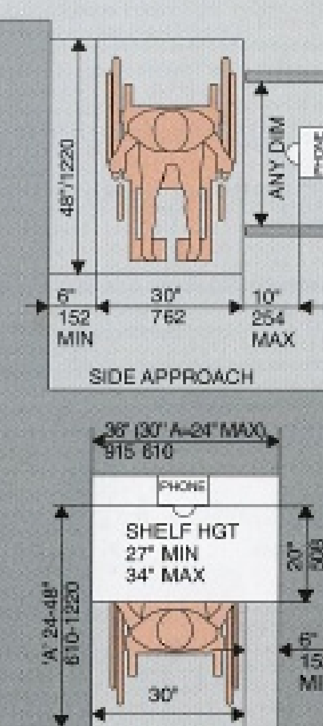
SAMPLE KITCHEN



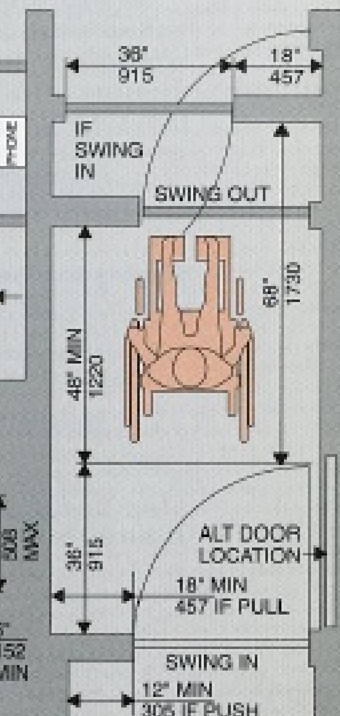
SAMPLE DINING AREA



PUBLIC PHONES



LOBBY DOORS



Telecommunication Devices for the Deaf

A TDD is used by a person with a hearing impairment or a communication disorder. The TDD (sometimes called a text phone) has a read-out monitor and a keyboard on which messages are input. The TDD can also be used as a credit-card phone.

A text phone has provision for at least a 10 x 10" (255 x 255 mm) shelf with a minimum 6" (150 mm) vertical clearance space to accommodate a portable text phone. In this case, a 110-volt outlet must be supplied, and the handset cord from the coin set must be of ample length to couple with the portable text phone.

TDDs may have fax in-and-out capability.

These phones will carry the international TDD symbol, which represents a horizontal handset over a keyboard.

The highest reachable point (coin slot or function key) must not exceed 54" (1370 mm) for the side approach of a wheelchair, or 48" (1219 mm) for the forward approach.

On semi-enclosed booths, all wing-style walls must be 27" (685 mm) from the floor or pavement, or lower, in order to aid and protect a person who walks with a cane.

For wing walls under 24" (610 mm) deep, the space between the walls should be a minimum 30" (760 mm); for wing walls deeper than 24" (610 mm), the space should be a minimum 36" (915 mm). In either case, recess the shelf 4" (100 mm). (A shelf may be flush with the wall edges for a side approach only.)

Semi-enclosed booths may be wall-mounted or mounted on a post or pylon.

Hearing-Aid Compatibility and Assistive Listening Systems

- Use the symbol of volume control, which represents a vertical handset with radiating curves coming out of the receiver end (facing right).
- Assistive listening systems should be installed in assembly areas.

These systems are identified by the international symbol of access for hearing loss.

Considerations for the Visually Impaired

Although service dogs are trained to recognize and avoid hazards, most people with severe vision impairment are trained to use a cane in two ways. The first technique is used in uncontrolled areas while the second technique is used in familiar areas.

1. The cane is swung in arcs to tap the ground from side to side, touching points about 6" (150 mm) outside each shoulder. In this way, walls and obstructions not higher than 27" (685 mm) can be detected; the user's hands or arms will hit objects higher than 27" (685 mm), and confusion and injury can result.
2. The cane is held fixed at a diagonal in front of the user, with the tip almost touching the floor beyond one shoulder and the handle or grip outside the opposite shoulder.

Areas that extend 27 to 80" (685 to 2030 mm) under staircases must be closed off for safety reasons

Further considerations for protecting the visually impaired follow:

- For safety in walking parallel to a wall, projections are permissable if they clear the floor by 27" (685 mm) or lower and if a passage of at least 36" (915 mm) minimum width remains.
- Sign boxes and the like can project a maximum of 4" (100 mm) at any height above 27" (685 mm) for passage parallel to a wall.
- Wall-mounted objects such as telephones may project if the shelf height is no greater than 27" (685 mm).
- Pylon-mounted telephones can project only 12" (305 mm) from the pylon; they are allowable above the 27" (685 mm) limit, because the cane will detect the pylon.
- Overhead signs must never reduce the head clearance of 80" (2030 mm), measured to the floor.
- Floor-grate openings may be a maximum of 0.5" (13 mm) in the direction of travel. Any longer dimension for such an opening must be perpendicular to the travel direction.
- People who have difficulty walking or who use crutches, canes, or walkers are susceptible to slipping or tripping. Provide safe walking surfaces on all walkways and stairs.

Signage

Overhead signs placed higher than 80" (2030 mm) must have capital letters a minimum of 3" (75 mm) in height ("all cap" lettering is not required) for a viewing distance of 75 feet (23 m). The minimum letter height is 0.625" (16 mm) for a closer viewing distance of 15 feet (4.6 m).

All lettering should have a width-to-height ratio of between 3:5 and 1:1 and a stroke-width-to-height ratio between 1:5 and 1:10.

Use a matte or other nonglare finish. Acceptable letter typefaces would include the following:

Serifs

Bodoni

Century Schoolbook

Garamond, Garamond Bold

Glypha, Glypha Bold

Palatino

Times Roman

Sans-serifs

Helvetica, Helvetica Bold, Helvetica Condensed, and Helvetica Condensed Bold

Futura, Futura Condensed Bold

Univers 55

Symbol signs with raised and Braille characters should be installed 60" (1525 mm) from the sign center to the floor. Letter heights of 0.625–2" (16–50 mm) should be located below the symbol and raised 0.031" (0.79 mm) accompanied by grade–2 Braille. Locate these signs well away from dangerous areas and where permanent identification is needed for rooms and spaces.

Elevators for Wheelchair Users

For wheelchair accessibility, the door of an elevator must be a minimum 36" (915 mm) wide. There are two acceptable elevators:

1. One has the door to one side, and the minimum interior measures 68" (1730 mm) wide and 51" (1291 mm) deep.
2. Another version has the door on the center line, and the minimum interior is 80" (2030 mm) wide and 51" (1291 mm) deep. With the door centered, the control panel may be located on either side of the door.

Take note of the following items concerning the elevator control buttons and other features:

- The control buttons, of 0.75" (19 mm) diameter minimum, may be raised or flush.
- The floor designations and symbols preferably appear to the left of each button. The bottom row of buttons has the emergency alarm on the left and a raised octagon symbol to the left of the emergency stop. The button above the emergency stop is the "Door Closed" button. Above left is the "Door Open" button.
- Floor designations are raised and illuminated. Braille is also provided for the visually impaired.
- No button is to be higher than 54" (1370 mm) for the side approach or 48" (1219 mm) for the front approach. The center line of any emergency button must be no lower than 35" (890 mm) above the finished floor.
- The clearance between the car platform sill and the edge of any hoistway landing should not exceed 1.25" (32 mm).
- Elevator position indicators are located above the control panel or above the door. As the car passes or stops, the floor indication will light up and an audible signal will sound. Floor numeral heights are 0.5" (13 mm) minimum. The audible signal is no less than 20 decibels and its frequency no higher than 1500 Hz.
- All hoistway entrances should have raised and Braille floor designations of 2" (51 mm) in height on both door jambs. The center of these designations is 60" (1525 mm) above the finished floor.
- Illuminated fixtures indicating an elevator's up or down direction should be mounted 72" (1830 mm) above the floor. Their smallest dimension should be 2.5" (64 mm).
- Call buttons of at least 0.75" (19 mm) diameter should be centered 42" (1065 mm) above the floor.

Platform Lifts for Wheelchairs

Platform lifts for wheelchairs are acceptable, but they must comply with the ASME A17.1 Safety Code for Elevators and Escalators, Section XX (1990).

Checklist for the Blind or Visually Impaired

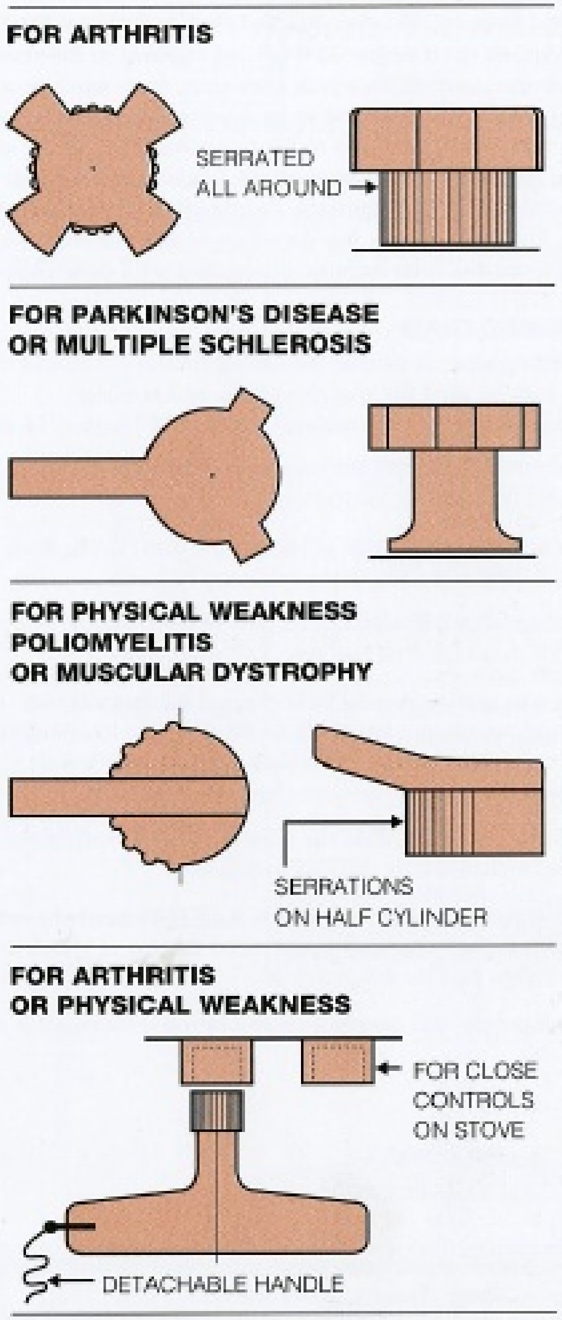
Consider the following when designing for the blind or visually impaired:

- Use 42" (1067 mm) railings with 6" (152 mm) curbs around dangerous areas.
- Avoid projections, tripping hazards, and low-hanging obstructions.
- Avoid open stairs and stair nosings.
- Floor openings of 0.6" (15 mm) or smaller exclude cane tips.
- Right-angle grid patterns are easier to comprehend than curves and serpentines.
- Use braille.
- Raised characters should be 0.4" (10mm) thick, and placed at a height of 60" (1500 mm) above the floor.
- Knurl the back surfaces of handles and knobs on doors leading to dangerous areas.
- Add audible signals to visual signals.
- Gas ranges are preferable to electric because they give audible cues.
- Hard surfaces aid sound detection.
- To avoid tripping, limit changes in floor levels.

Checklist for the Deaf or Hard-of-Hearing

Consider the following when designing for the deaf or hard-of-hearing:

- Add visual signals and displays to audible signals.
- Emphasize printed matter, symbols, and pictures.
- Provide telecopy or fax.
- Increase the volume of audio signals, e.g., amplify telephones and ringers.
- Provide text phone for speech impairment.



MANUAL CONTROLS FOR THE DIFFERENTLY ABLED

SEATING

Seating is an interesting study, because people come in assorted sizes and proportions and their tasks vary. People sit to eat, sit to commute to work, sit at home in the evenings to converse, to read, to watch television, or to work on a hobby. Some chairs appear to be designed with no thought given to the person who is to be accommodated, to the seat size or height, to the support of the lumbar region, or to the correct design of the armrests. People often have a favorite chair, but many people buy furniture mostly for the sake of appearance and later become dissatisfied with their choice.

THE DINING CHAIR

The dining chair is simple; the sitting time is short; and the chair may be used for study, reading, and writing.

The standard dining table of today is 28" high (711 mm).

- The vertical distance between seat front edge and table top is best at 9–12" (230–305 mm).
- The seat top-front edge is 16.5" (420 mm) to the floor and 11.5" (290 mm) below the table top.
- The seat depth should not exceed 16" (405 mm). The width should not be less than 16" (405 mm).
- The seat surface should be level, and lumbar support should maintain a hip angle of 90–95°. The knee angle is 90° or greater or less. Note that the hip angle is not jackknifed and will not interfere with digestion.
- Padding is preferred on the seat: 0.75" (19 mm) of thick foam with an easily cleaned upholstery.
- The center of lumbar support is 9.5" (240 mm) above the seat. Lumbar area height is 9" (230 mm), and width is 13" (330 mm) minimum.
- Small people will dangle their feet unless a footstool is used.

Recommendations on seating requirements were adapted from the following sources: Pheasant, *1986;* MIL-STD-1472C, *1981;* Grandjean, *1987;* ANSI/HFS 100, *1988; and* Humanscale 1/2/3 *and* 7/8/9.

A UNIVERSAL WORK CHAIR

The universal work chair is more complicated than the dining chair because it must accommodate two postures, one erect and the other relaxed. The latter simulates an automobile seat, which many adults favor.

- The top-front edge of the seat requires an adjustment of 5" (125 mm), so that the seat can go from 14.5" (370 mm) to 19.5" (495 mm) to accommodate all adults.
- The seat size, front to back, should not be more or less than 16" (406 mm) to accommodate all adults.
- The seat width should be 16–22" (406–560 mm).
- The seat cushion is to be 2" (51 mm) of medium foam with no bottoming.
- Seat angle adjustment: 0–15° from horizontal.
- Back angle adjustment: 0–15° from vertical.
- Backrest height: 25" (635 mm) for thoracic and shoulder support; 36" (915 mm) for head support; and 15.7" (400 mm) for arm reach-over.
- The center of lumbar height (adjustable from seat reference point): 7–11.5" (178–292 mm). In-and-out adjustment should be 2" (51 mm) minimum.
- The backrest cushion should be 1–2" (25–51 mm) of soft foam with a curved back to prevent side sway; too much concavity compresses the lungs. A radius of 40" (1000 mm) seems to be acceptable.
- Upholstery should provide comfort, ventilation, and friction. Avoid coarsely textured fabrics.
- Back support is not required 3" above the seat; this space helps provide clearance for the buttocks.
- A rounded top-front edge of seat cushion and bottom edge of backrest: 0.5" (12.7 mm) radius.
- Armrest spacing, for access: 19" (483 mm). Armrest widths: 2–3.5" (51–89 mm). Armrest lengths: 10" (254 mm) forward of seat reference point for use at a table, or 12" (305 mm) if not for use at a table. Pad armrests softly with textured material; 0.5" radius (12.7 mm) all around the top edges.
- The chair should swivel and have 5 or 6 feet for stability.

SEATING VARIATIONS

The drawing that illustrates seating variations shows four postures.

- A work chair for attention or alertness.
- A relaxing chair for thinking, everyday use, and travel.
- An easy chair with backrest that slopes 30 degrees or more from the vertical; this requires a headrest, and an ottoman would be beneficial.
- A reclining chair, which is best when designed for an individual. The fully reclined posture is not good for reading, watching television, or conversation, for the sitter's vision is turned upward. A pedestal support is not satisfactory for this chair's back load.

Seat height at the front edge is best if adjustable 5" (125 mm), so that the seat can move from 14.5" (370 mm) to 19.5" (495 mm), measured vertically to the finished floor.

Padding should be of medium foam about 2" thick (51 mm). Also pad armrests 0.5" (13 mm) with 0.5" radius (13 mm) all around the top edges.

SEATING AT COMPUTER STATIONS FOR MEN AND WOMEN

Refer to "A Universal Work Chair," above, for most of the detailed information on seating.

Beginning with the diagram showing women of the 1 to the 99 percentiles working at a computer station, note first that the keyboard is movable and can be angled; also, the monitor is rotatable, vertically adjustable, and tiltable to minimize reflections.

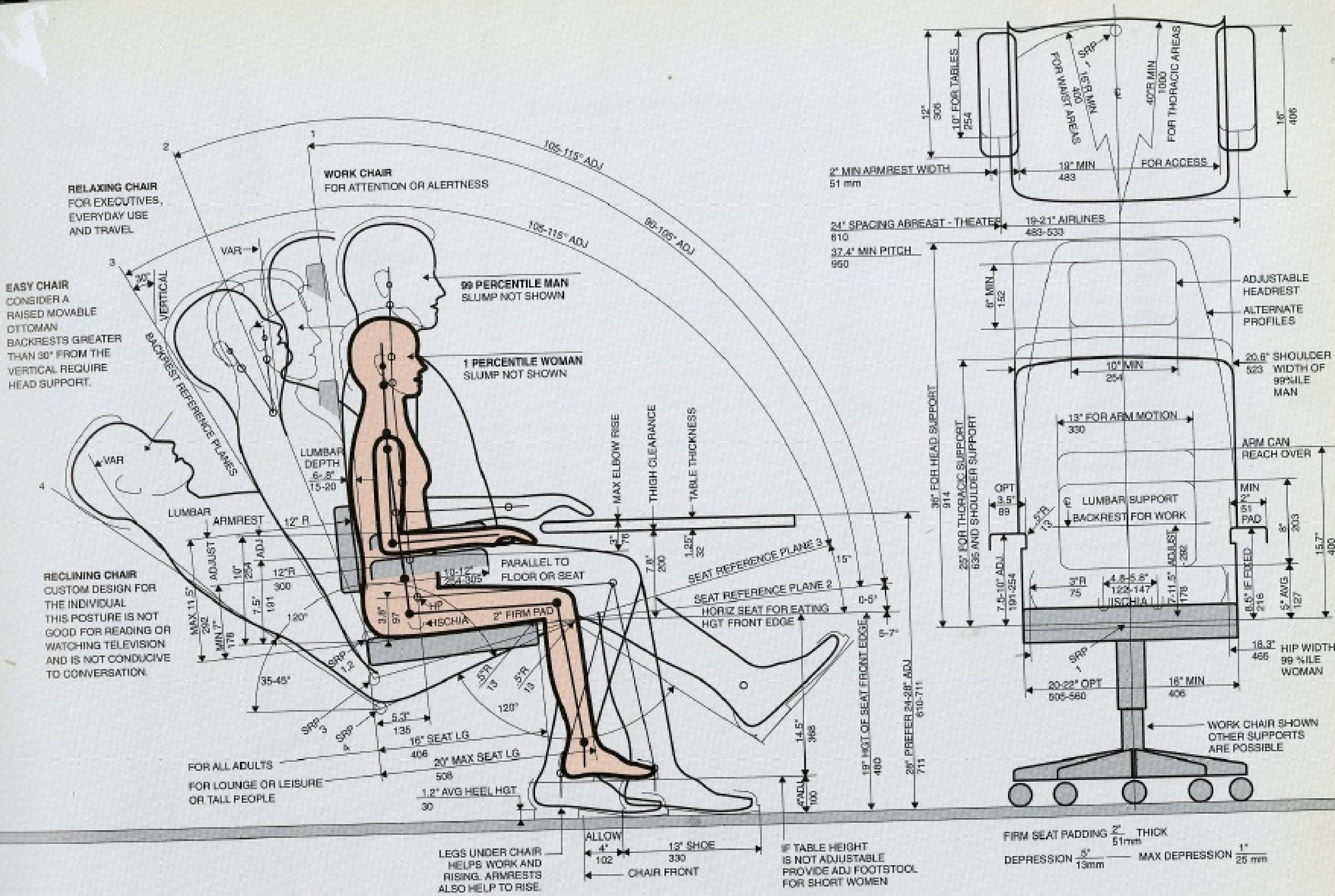
Operators like both the erect posture for short periods and the relaxed posture resembling the automobile seat for longer durations. The chair is adjustable.

The height of the table has an adjustable range of 23–29" (585–735 mm) for women only. A compromise fixed table height of 26" (660 mm) is acceptable for women, but not if a mouse is used with the table above the elbow height.

The small woman can have larger pregnancy dimensions.

Note that no extra foot support is shown.

Now refer to the diagram showing men of the 1 to the 99 percentiles working at a computer station. Note first that the keyboard is movable and can be angled; also, the monitor is rotatable, vertically adjustable, and tiltable to minimize reflections.



RELAXING CHAIR
FOR EXECUTIVES, EVERYDAY USE AND TRAVEL
WORK CHAIR
FOR ATTENTION OR ALERTNESS
EASY CHAIR
CONSIDER A RAISED MOVABLE OTTOMAN
BACKRESTS GREATER THAN 30° FROM THE VERTICAL REQUIRE HEAD SUPPORT.
RECLINING CHAIR
CUSTOM DESIGN FOR THE INDIVIDUAL
THIS POSTURE IS NOT GOOD FOR READING OR WATCHING TELEVISION AND IS NOT CONDUCIVE TO CONVERSATION.
99 PERCENTILE MAN
SLUMP NOT SHOWN
1 PERCENTILE WOMAN
SLUMP NOT SHOWN
105-115° ADJ
105-115° ADJ
90-105° ADJ
BACKREST REFERENCE PLANES
VERTICAL
LUMBAR DEPTH .6-.8" 15-20
LUMBAR
ARMREST
12" R
12"R 300
PARALLEL TO FLOOR OR SEAT
10-12" 254-305
MAX ELBOW RISE
THIGH CLEARANCE
TABLE THICKNESS
SEAT REFERENCE PLANE 3
SEAT REFERENCE PLANE 2
HORIZ SEAT FOR EATING
HGT FRONT EDGE
2" FIRM PAD
ISCHIA
HP
SRP
16" SEAT LG 406
20" MAX SEAT LG 508
5.3" 135
FOR ALL ADULTS
FOR LOUNGE OR LEISURE OR TALL PEOPLE
1.2" AVG HEEL HGT 30
LEGS UNDER CHAIR HELPS WORK AND RISING. ARMRESTS ALSO HELP TO RISE.
ALLOW 4" 102
13" SHOE 330
CHAIR FRONT
IF TABLE HEIGHT IS NOT ADJUSTABLE PROVIDE ADJ FOOTSTOOL FOR SHORT WOMEN
19" HGT OF SEAT FRONT EDGE 480
28" PREFER 24-28" ADJ 610-711 711
14.5" 368
2" MIN ARMREST WIDTH 51 mm
12" 305
10" FOR TABLES 254
16"R MIN 400 FOR WAIST AREAS
40"R MIN 1000 FOR THORACIC AREAS
19" MIN 483
FOR ACCESS
16" 406
24" SPACING ABREAST - THEATERS 610
19-21" AIRLINES 483-533
37.4" MIN PITCH 950
ADJUSTABLE HEADREST
ALTERNATE PROFILES
6" MIN 152
36" FOR HEAD SUPPORT 914
25" FOR THORACIC SUPPORT 635 AND SHOULDER SUPPORT
10" MIN 254
20.6" SHOULDER WIDTH OF 99%ILE MAN 523
13" FOR ARM MOTION 330
ARM CAN REACH OVER
LUMBAR SUPPORT
BACKREST FOR WORK
OPT 3.5" 89
MIN 2" 51 PAD
8" 203
15.7" 400
3"R 75
4.8-5.8" 122-147
ISCHIA
7.5-10" ADJ 191-254
7-11.5" ADJUST 178-292
8.5" IF FIXED 216
5" AVG 127
18.3" 465 HIP WIDTH 99 %ILE WOMAN
20-22" OPT 505-560
16" MIN 406
WORK CHAIR SHOWN OTHER SUPPORTS ARE POSSIBLE
FIRM SEAT PADDING 2" 51mm THICK
DEPRESSION .5" 13mm — MAX DEPRESSION 1" 25 mm

Men also prefer both the erect posture for short periods and the relaxed posture resembling the automobile seat for longer periods.

The height of the table has an adjustable range of 25–31" (635–785 mm) for men only. A compromise fixed table height of 28.25" (720 mm) is acceptable for men.

An alternate design is a fixed table height of 28.25" (720 mm) for women and men, if there is both an adjustable shelf for keyboard only, with a range of 23–28.25" (585–720 mm). The shelf should be large enough for using a mouse.

Note also the following:

- The monitor's height adjustment would be 7" (180 mm).
- The lumbar height would have a minimum adjustability of 7 to 11" (180 to 280 mm) up and down and 2" (50 mm) in and out.
- To prevent Carpal Tunnel Syndrome keep the forearm and wrist in a nearly straight line and take frequent rest periods.
- To avoid electromagnetic fields, keep the cathode-ray tube (monitor screen) at an arm's length away. The operator should be at least 48" (1220 mm) away from any other monitor.
- The cathode-ray tube should not be above the horizontal eye level and should not be below a 40-degree sight line, measured from the horizontal sight line.

CLASSIC CONSOLES FOR MEN AND WOMEN

Four classic consoles, modified from military design, accommodate women as well as men; their suitability ranges from the 1 percentile woman to the 99 percentile man. Note here that several types of foot support are shown to help smaller women and men.

The first console is simple, for see-over and no-see-over. The cathode ray tube is fixed on a 15° sloping panel. The keyboard is movable and tiltable on a 15" (380 mm) shelf, which permits an easy reach to controls on the monitor panel. The shelf height is 28" (710 mm).

Install only displays on the top panel area of the no-see-over console. Movable footstools are shown, but a footrest ring on the chair base is also a possibility.

The second console is a compound version that presents many panels running up to 68" (1725 mm). A movable keyboard on a 13" (330 mm) shelf, ample for an armrest or workbooks, is possible. The height is 28" (710 mm). Keys that are infrequently used can be installed on the 50–35° panel. No manual controls should go above the horizontal sight line of the small woman; only displays go above this line.

The seat for the first and second consoles is similar to the description under "A Universal Work Chair," above. A foot ring has been added on top of the caster supports for the compound console.

The foot space shown on both consoles will accommodate the 99 percentile man.

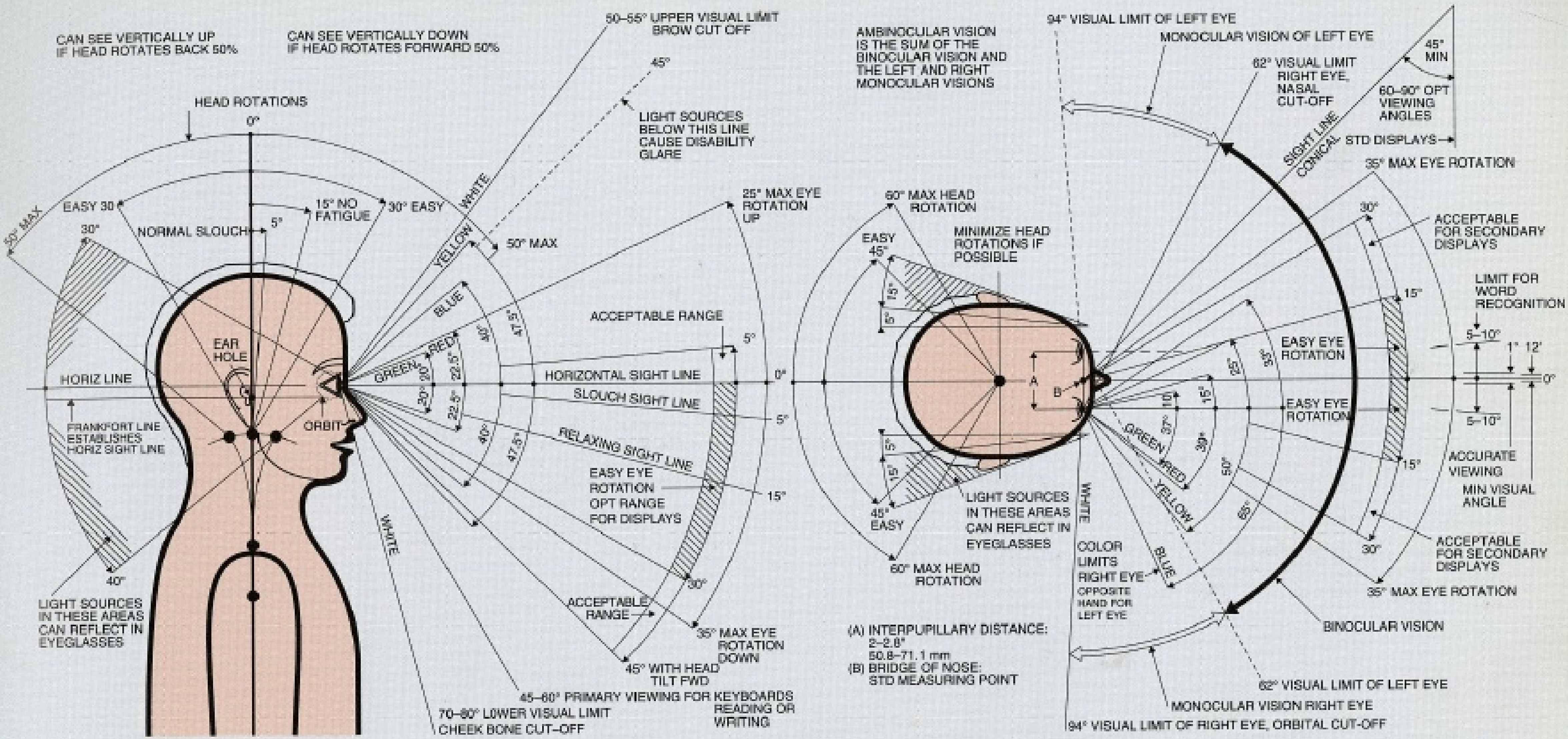
The sit/stand console is complicated; it can allow an operator to walk a long distance, if necessary. A chair 28–32" (710–815 mm) high is provided if work at one location is frequent. This chair carries a heel catch 12" (305 mm) above the finished floor. Since casters could be dangerous, only glides are shown. Alternate footrests with possible adjustments are shown mounted to the back wall of the console. Only a 10" (255 mm) shelf, at a height of 40" (1015 mm), is provided for note-taking, because the back panel is sloped away more for the standing man.

The optimum width is 24" (610 mm), and the maximum efficient width is 28" (710 mm). The sit/stand console can be as long as a wall, if required.

The fourth console is a wrap-around design that can be adapted to the first see-over or no-see-over console. In this design, the center panel is only 24" (610 mm) wide and has two supplemental panels 12" (305 mm) wide—one on each side—135° from the center panel.

In another version, the center panel has a 36" (915 mm) maximum width. Here, the supplemental panels are 120° from the center panel.

The wrap-around console doubles the work space available.



NEAREST SEEING DISTANCES (AVERAGE VALUES)

0 INFANTS 0–10 WEEKS ARE LEGALLY BLIND
2.4"/61mm YOUTHS
4"/102mm AGE 20
8.75"/222mm AGE 40
40"/1016mm AGE 60·

PRACTICAL READING DISTANCES FOR ADULTS

13"/330mm MIN FOR CLOSE VIEWING
16"/406mm MIN READING DISTANCE
18–24"/457–610mm READING STD DISPLAYS
28"/711mm DISPLAYS WITHIN REACH
ANY DISTANCE IF DISPLAY IS DESIGNED FOR IT.

COLOR BLIND PERSONS

3.5 PERCENT MEN
0.8 PERCENT WOMEN

WEAR GLASSES

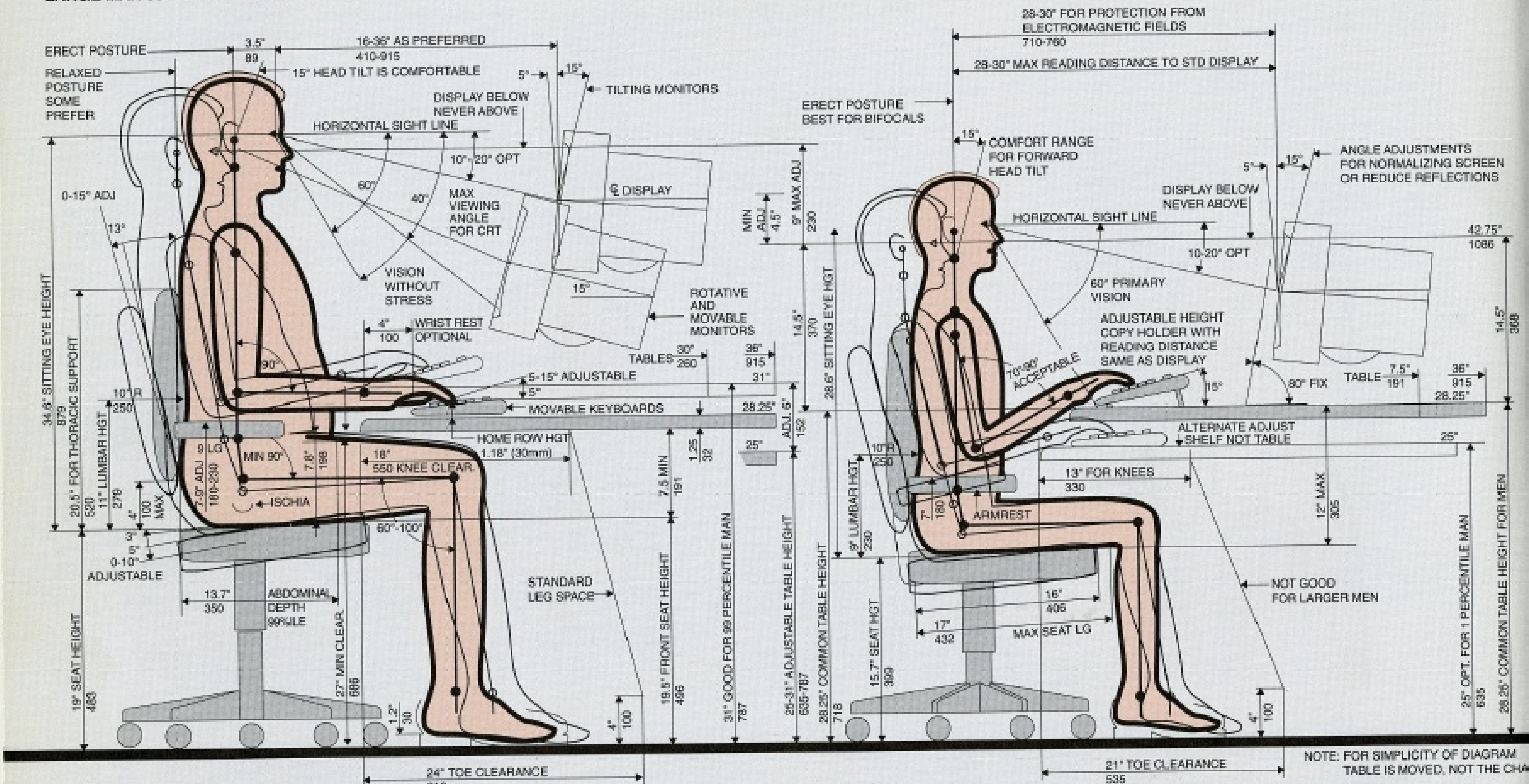
54 PERCENT OVER 6 YR
US POPULATION

CHART INSTRUCTION FOR USE AND INFORMATION

COLOR LIMITS ROTATE WITH CHOSEN SIGHT LINE.
EYE ROTATIONS TILT WITH HEAD ROTATIONS.
LIMITS FOR COLOR DISCRIMINATION VARY WITH HUE, AREA, CONTRAST, AND ILLUMINATION.
IRREGULAR PATTERNS OF COLOR VISION CAUSE DISCREPANCY OF YELLOW AND BLUE POSITIONS.
AGE 16–35 YR IS BEST FOR COLOR DISCRIMINATION, OVER 55 YR IS POOR.

LARGE MAN 99 PERCENTILE US POPULATION

SMALL MAN 1 PERCENTILE US POPULATION



FOR COMFORT, SAFETY AND PROTECTION USE ADJUSTABLE TABLE HEIGHTS. FOR MEN ONLY ADJUST 25"-31" (635-787). ALTERNATE: USE COMPROMISE FIXED HEIGHT 28.25" (718) AND PROVIDE ADJUSTABLE CHAIR HEIGHT 15.7"-19" (399-483).

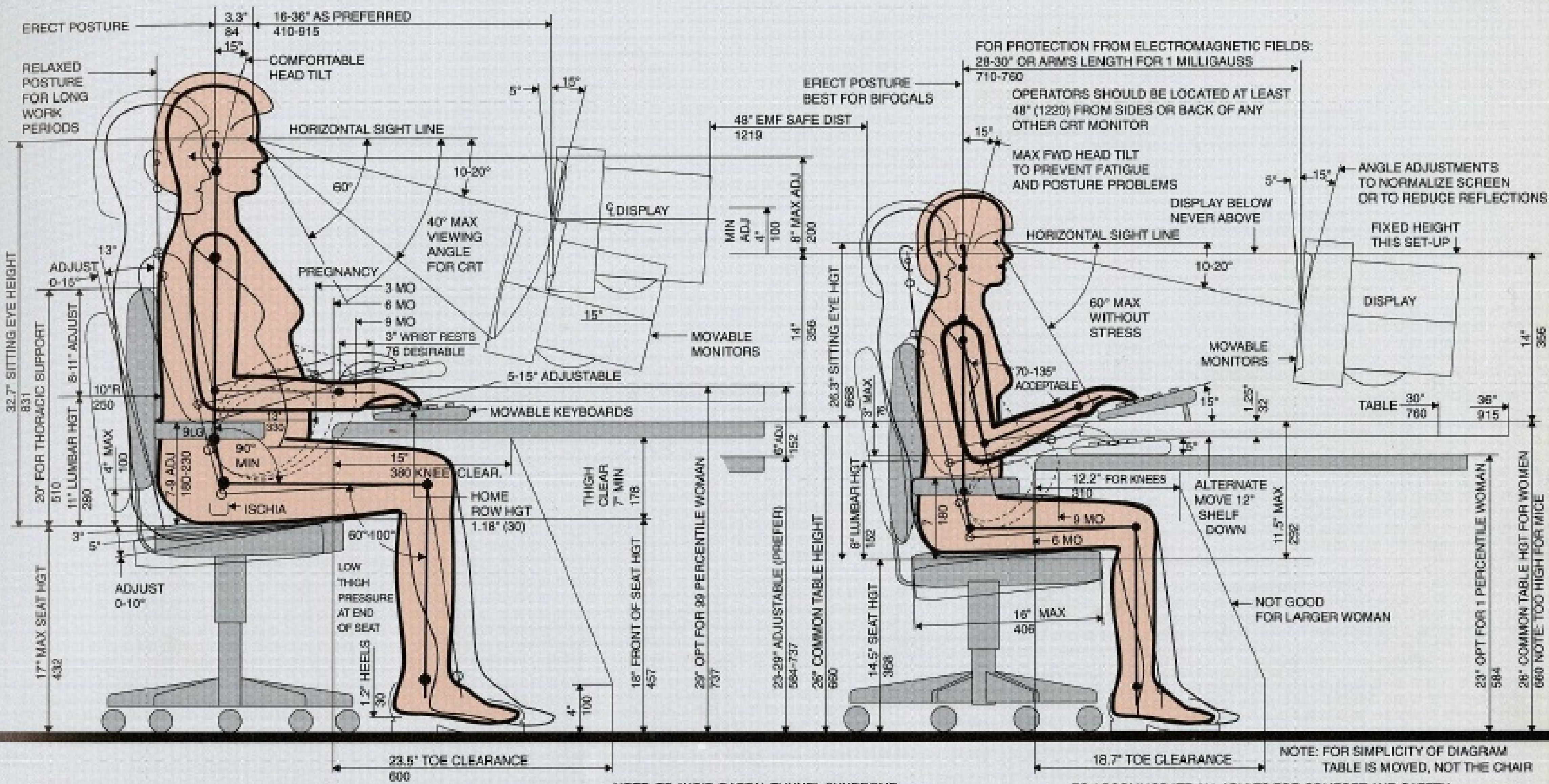
TO ACCOMMODATE ALL ADULTS (MEN AND WOMEN) PROVIDE ADJUSTABLE TABLES 23"-31" (584-789) AND ADJUSTABLE CHAIRS 14"-19" (356-483).

ALTERNATE DESIGN USE A FIXED TABLE HEIGHT OF 28.25" (718) FOR ALL ADULTS WITH ADJUSTABLE HEIGHT SHELF FOR KEYBOARD ONLY 23"-28.25" (584-718).

PREFER MONITOR HEIGHT ADJUSTMENT OF 7" (178)

LARGE WOMAN 99 PERCENTILE US POPULATION

SMALL WOMAN 1 PERCENTILE US POPULATION



TWO WAYS TO AVOID THE USE OF FOOT STOOLS:

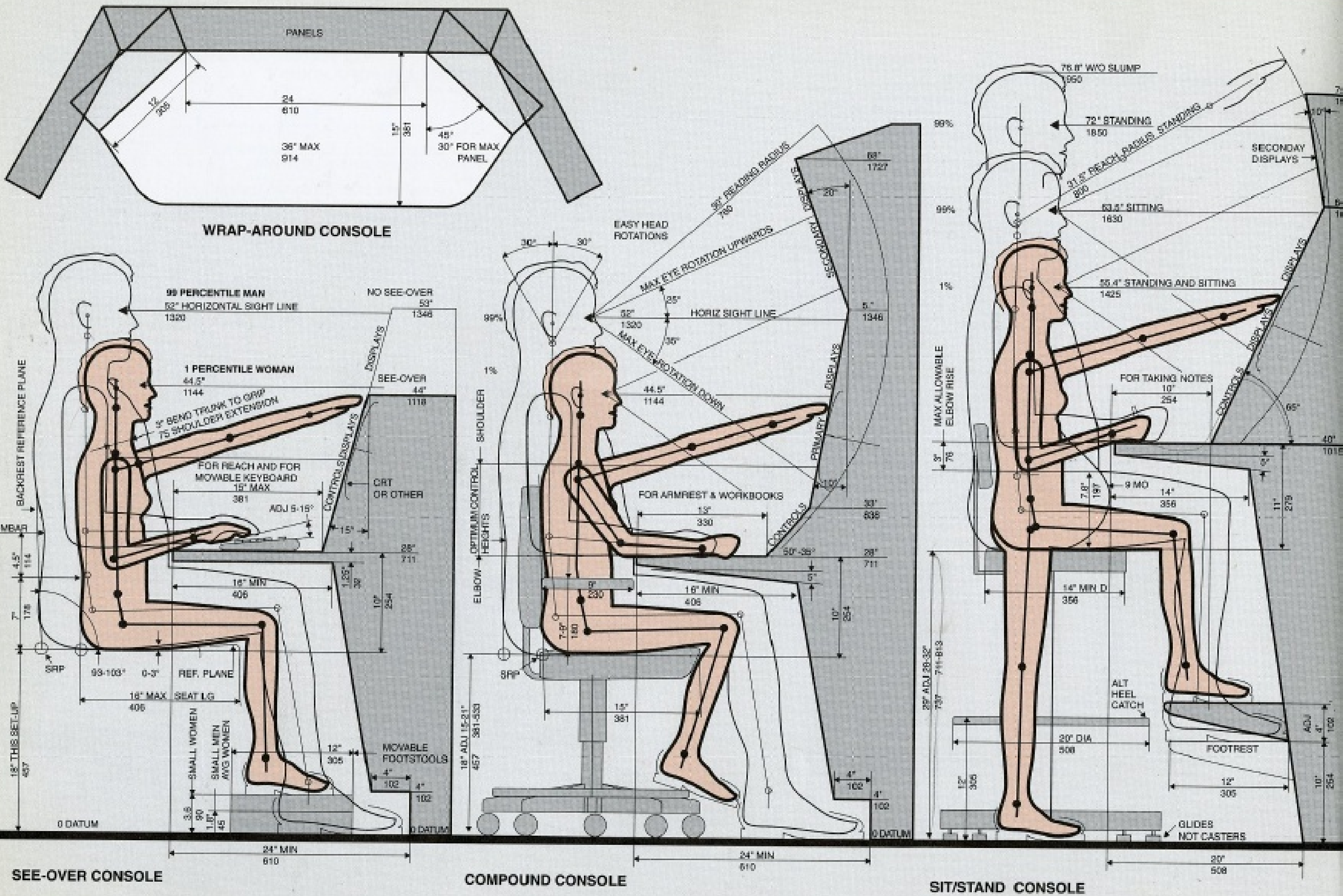
1. PROVIDE ADJUSTABLE TABLE HEIGHTS 23-29" FOR WOMAN ONLY
   584-737
2. ACCEPT A COMPROMISE FIXED TABLE HEIGHT 26" FOR WOMEN
   660

NOTE: NOT GOOD FOR MOUSE IF TABLE IS ABOVE ELBOW

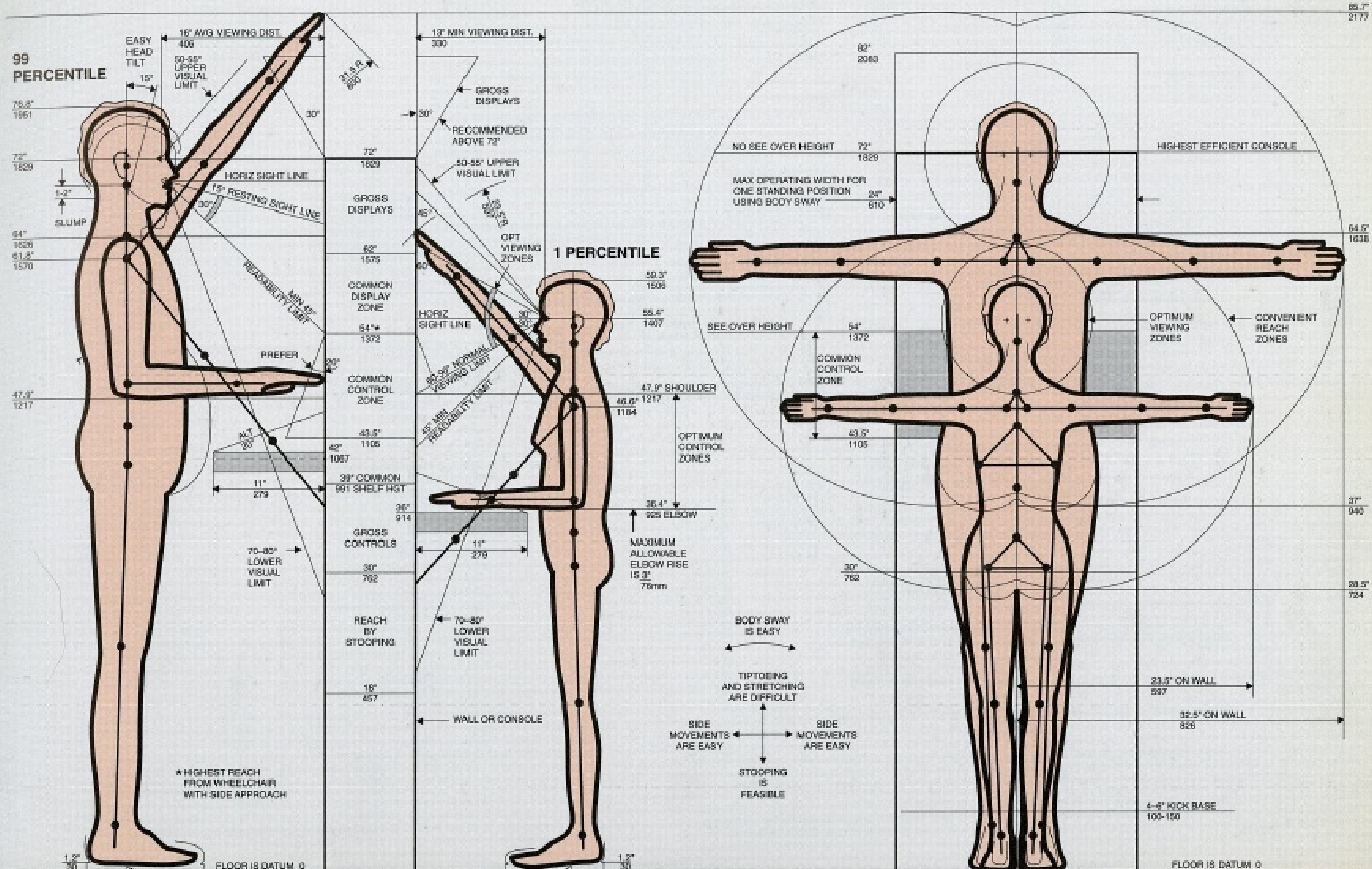
NOTE: TO AVOID CARPAL TUNNEL SYNDROME
KEEP HAND AND FOREARM IN A STRAIGHT LINE
AND TAKE FREQUENT REST PERIODS.
ELBOW ANGLES MAY VARY 70°–135°.

TO ACCOMMODATE ALL ADULTS FOR COMFORT AND SAFETY:
USE ADJUSTABLE TABLE HEIGHTS 23-31"
584-784

AND SEAT HEIGHT ADJUSTABILITY 14-19"
356-483



PANELS
12
305
24
610
15"
381
45°
30° FOR MAX PANEL
36" MAX
914
WRAP-AROUND CONSOLE
99 PERCENTILE MAN
52" HORIZONTAL SIGHT LINE
1320
NO SEE-OVER
53"
1346
1 PERCENTILE WOMAN
44.5"
1144
SEE-OVER
44"
1118
5° BEND TRUNK TO GRIP
75 SHOULDER EXTENSION
DISPLAYS
CONTROLS/DISPLAYS
FOR REACH AND FOR MOVABLE KEYBOARD
15" MAX
381
ADJ 5-15°
CRT OR OTHER
15°
28"
711
BACKREST REFERENCE PLANE
LUMBAR
4.5"
114
7"
178
1.25"
32
10"
254
16" MIN
406
SRP
93-103°
0-3°
REF. PLANE
16" MAX SEAT LG
406
18" THIS SET-UP
457
SMALL WOMEN
SMALL MEN AVG WOMEN
3.5"
90
1.8"
45
12"
305
MOVABLE FOOTSTOOLS
4"
102
4"
102
0 DATUM
0 DATUM
24" MIN
610
SEE-OVER CONSOLE
30°
30°
EASY HEAD ROTATIONS
99%
1%
30" READING RADIUS
760
MAX EYE ROTATION UPWARDS
25°
52"
1320
HORIZ SIGHT LINE
35°
MAX EYE ROTATION DOWN
44.5"
1144
SECONDARY DISPLAYS
20°
68"
1727
53"
1346
PRIMARY DISPLAYS
10°
SHOULDER
OPTIMUM CONTROL HEIGHTS
ELBOW
FOR ARMREST & WORKBOOKS
13"
330
CONTROLS
50°-35°
33"
838
28"
711
5"
9"
230
16" MIN
406
10"
254
7-8"
180
SRP
15"
381
18" ADJ 15-21"
457 381-533
4"
102
4"
102
0 DATUM
24" MIN
610
COMPOUND CONSOLE
76.8" W/O SLUMP
1950
99%
72" STANDING
1850
31.5" REACH RADIUS STANDING
800
SECONDAY DISPLAYS
10°
99%
63.5" SITTING
1630
1%
55.4" STANDING AND SITTING
1425
DISPLAYS
DISPLAYS
MAX ALLOWABLE ELBOW RISE
3"
76
FOR TAKING NOTES
10"
254
CONTROLS
65°
40"
1015
5"
7.8"
197
9 MO
14"
356
11"
279
14" MIN D
356
28" ADJ 28-32"
737 711-813
ALT HEEL CATCH
20" DIA
508
12"
305
ADJ 4"
102
FOOTREST
12"
305
10"
254
GLIDES NOT CASTERS
20"
508
SIT/STAND CONSOLE


99 PERCENTILE
1 PERCENTILE
16" AVG VIEWING DIST. 406
13" MIN VIEWING DIST. 330
EASY HEAD TILT
50-55° UPPER VISUAL LIMIT
HORIZ SIGHT LINE
15° RESTING SIGHT LINE
READABILITY LIMIT
GROSS DISPLAYS
COMMON DISPLAY ZONE
COMMON CONTROL ZONE
GROSS CONTROLS
REACH BY STOOPING
RECOMMENDED ABOVE 72"
OPT VIEWING ZONES
70-80° LOWER VISUAL LIMIT
WALL OR CONSOLE
47.9" SHOULDER 1217
36.4" 925 ELBOW
OPTIMUM CONTROL ZONES
MAXIMUM ALLOWABLE ELBOW RISE IS 3" 76mm
39" COMMON 991 SHELF HGT
* HIGHEST REACH FROM WHEELCHAIR WITH SIDE APPROACH
FLOOR IS DATUM 0
NO SEE OVER HEIGHT
HIGHEST EFFICIENT CONSOLE
MAX OPERATING WIDTH FOR ONE STANDING POSITION USING BODY SWAY
SEE OVER HEIGHT
OPTIMUM VIEWING ZONES
CONVENIENT REACH ZONES
BODY SWAY IS EASY
TIPTOEING AND STRETCHING ARE DIFFICULT
SIDE MOVEMENTS ARE EASY
STOOPING IS FEASIBLE
23.5" ON WALL 597
32.5" ON WALL 826
4-6" KICK BASE 100-150

RESIDENTIAL SPACE CONSIDERATIONS

Guidelines presented by Neufert, 1970; Panero and Zelnik, 1979; and the American Institute of Architects, 1988, were utilized to formulate the residential diagrams that follow.

BEDROOMS

Four bedrooms are shown in this illustration.

1. The first example (upper left) represents a comfortably minimal provision of most of the amenities that are desired in a bedroom. This room has the possibility of three beds: the first is a full, or double, bed; the second is a queen-size; and the third is a king-size. Note that the bed could not be better placed and that keeping all the furniture below 30" (762 mm) makes the room look larger.
2. The second bedroom (lower left) is nearly minimal for a single occupant.
3. The third bedroom is more luxurious. There are two beds and two desks.
4. The last bedroom is for two occupants (siblings or students) and provides individual study and storage areas.

DINING SPACES

The first dining room measures 10'8" x 13'6" (3250 x 4115 mm). There is a 24" (914 mm) clearance space behind the chairs all around the table. This permits access for a person to serve all seated diners.

In the second dining space, with the table against the wall, the space needed for clearance and for serving diners must be considered.

Included here are three categories of restaurant seating: an economical spacing, an intermediate spacing, and space for luxurious seating. There are side tables and floating tables.

Dining booths for two and four occupants are shown. The seating profile is important for comfort, as is the requirement for a 10–12" (254–305 mm) vertical seat to table dimension. The seat should be level when occupied. The backrest should be angled away at least 5°.

KITCHEN AND BATHROOM LAYOUTS

At the lower left, an L-shaped kitchen is represented. The primary work path is defined as a triangle of 10 x 6 x 5 ft. This kitchen is preferable for accommodating two people. The separate work table is advantageous for food preparation.

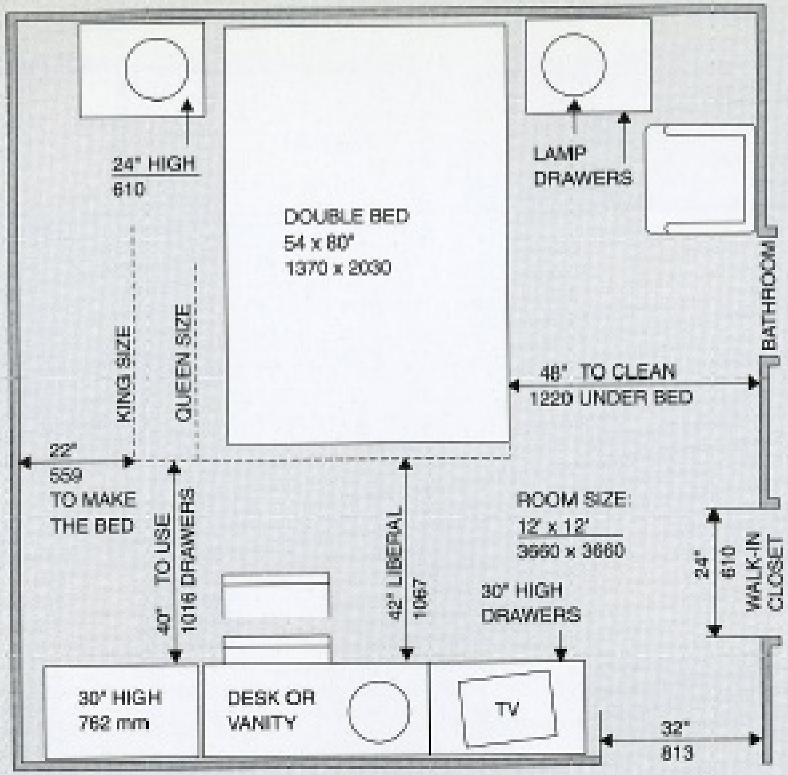
Above left, in the two corridor kitchens, the wider one allows two people to prepare meals simultaneously. The narrow version is a nearly minimal, but still efficient, kitchen for one person.

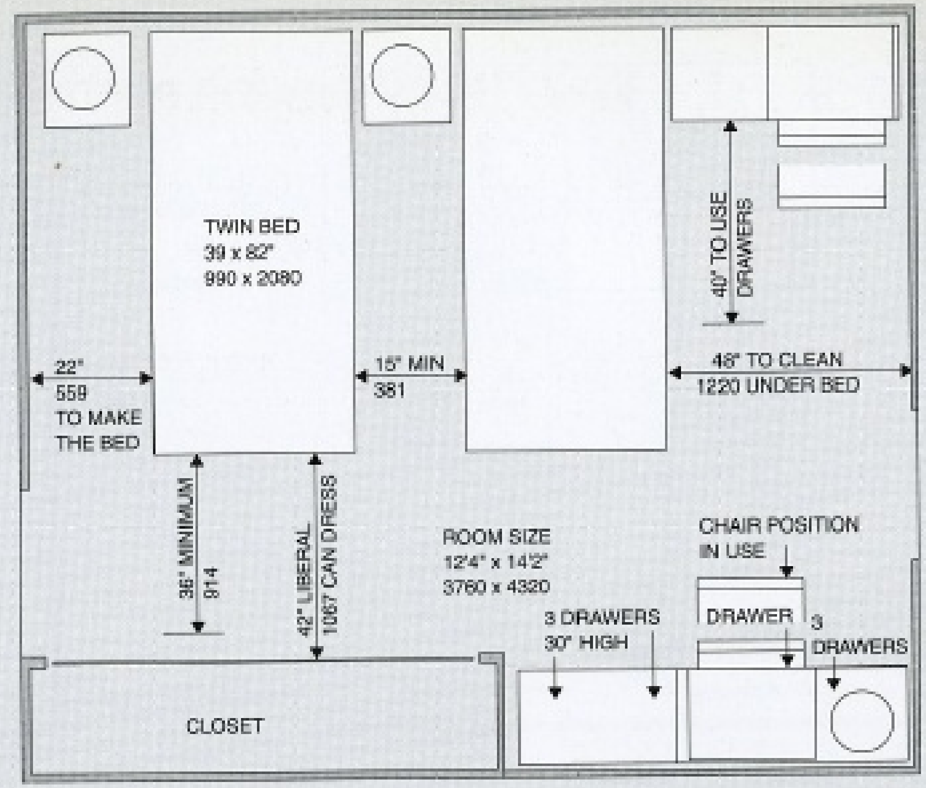
The U-shaped kitchen is designed for efficient use by one person.

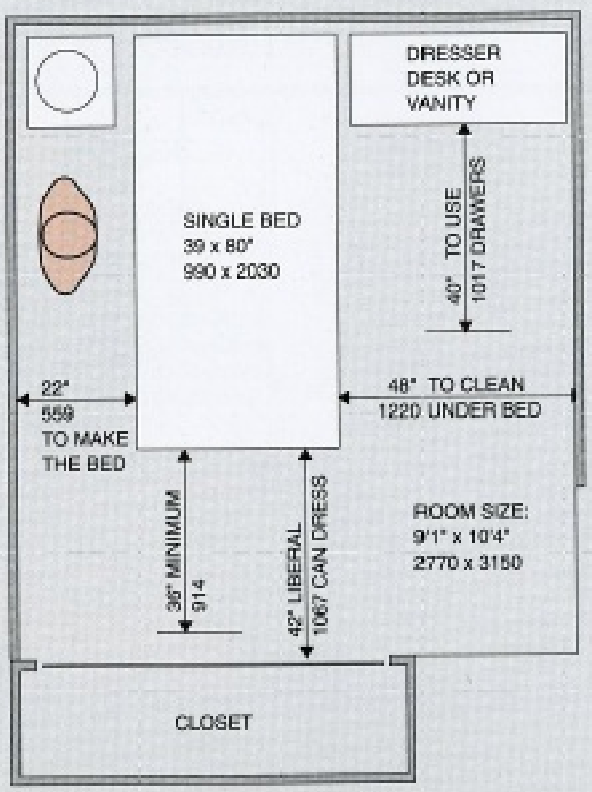
The bathroom at lower center is rather minimal, but with certain advantages. It is 6 ft wide, and the bathtub has an extra seat for the elderly. The toilet has a lower-capacity water tank and a lower silhouette. The lavatory is 36" wide, with a full-width mirror and a medicine cabinet on each side. The bottom offers a completely closed-in storage area.

The layout on the lower right represents the most economical bathroom. Except for the pedestal-style lavatory and the omission of the bathtub seat, it is similar to the preceding bathroom design.

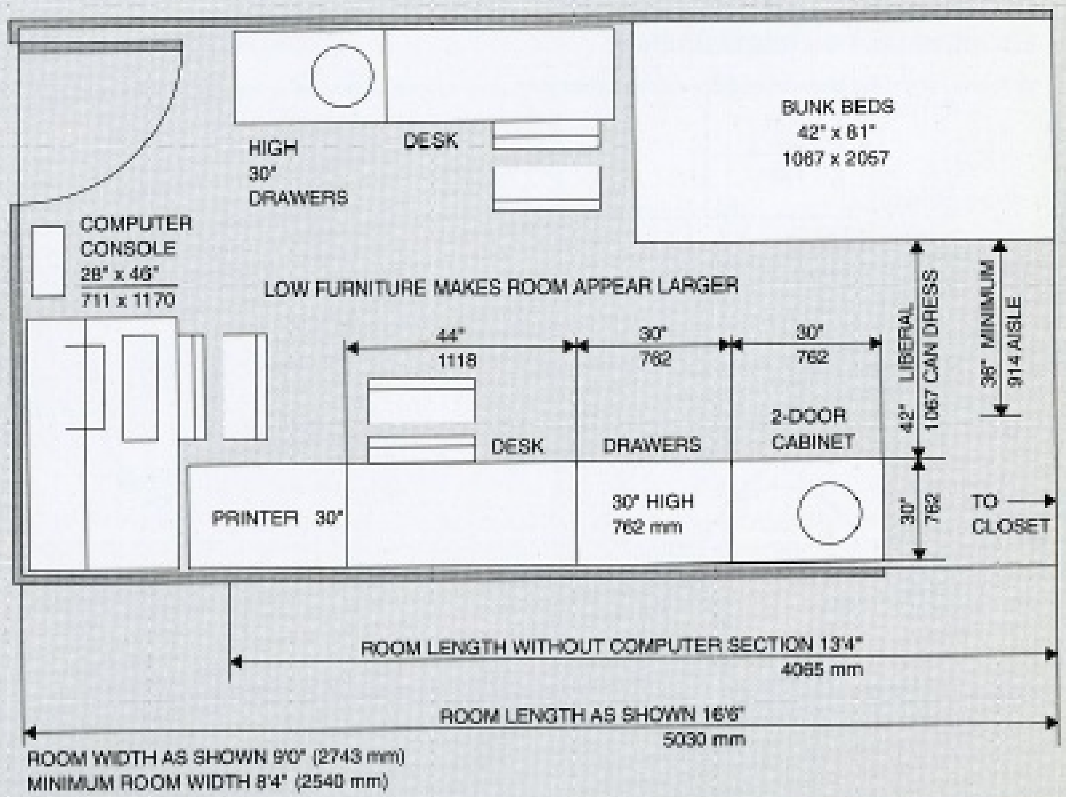
BEDROOMS





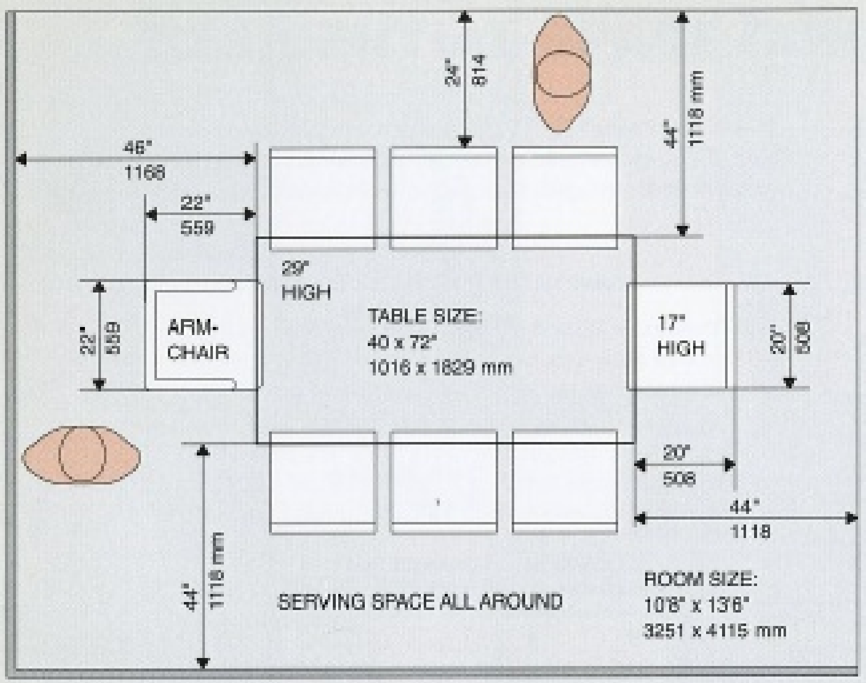


BEDROOM AND STUDY

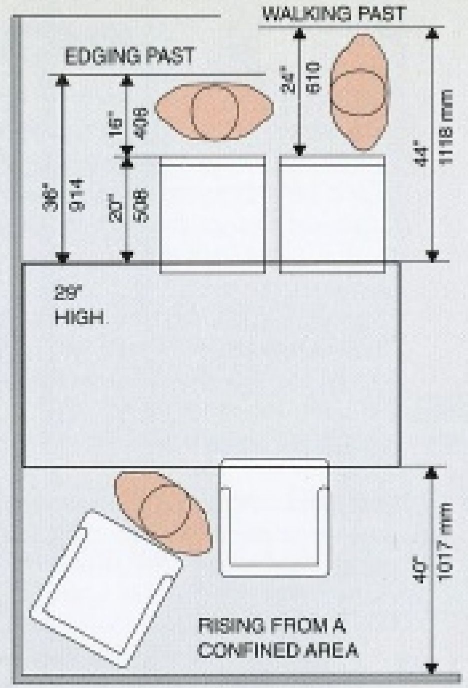


53

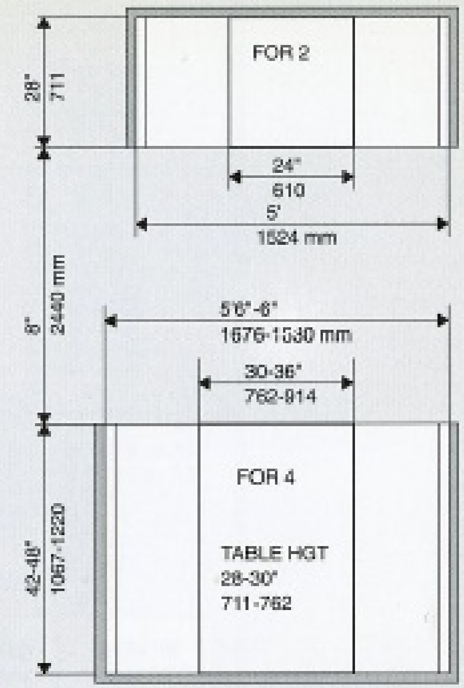
DINING AREAS



DINING AREAS



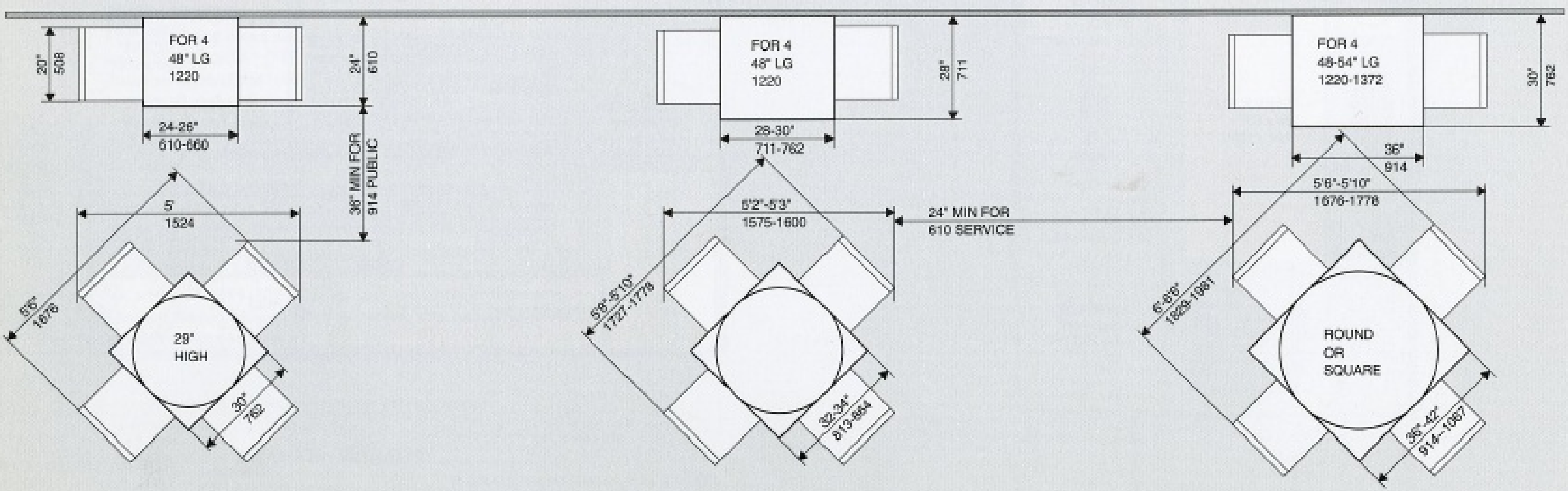
DINING BOOTHS



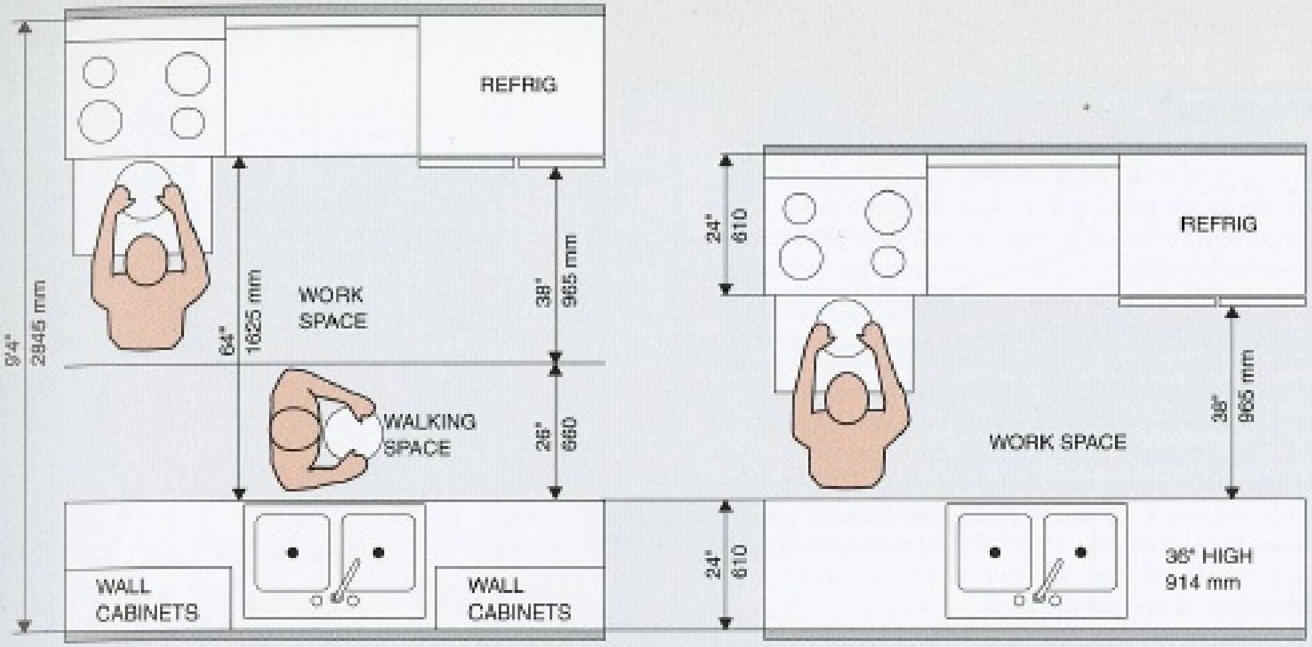
ECONOMICAL FOR RESTAURANTS

INTERMEDIATE

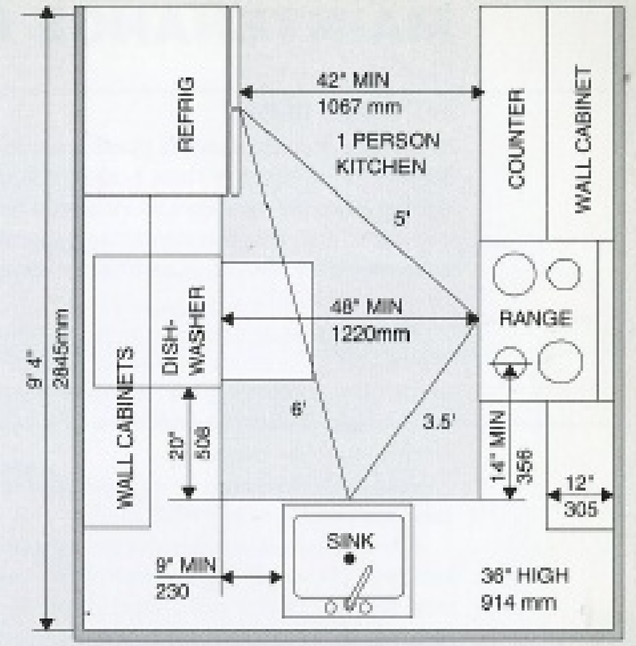
LUXURIOUS



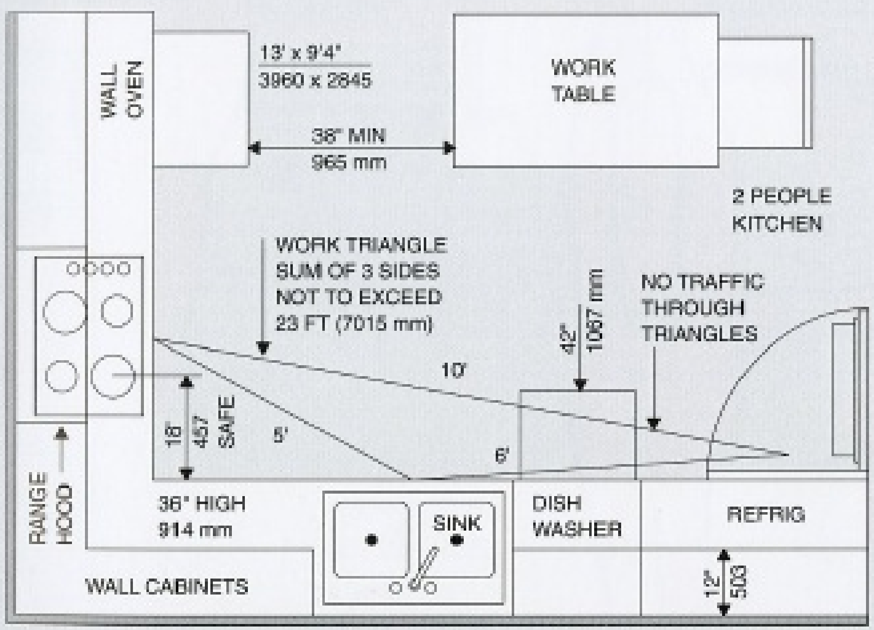
CORRIDOR KITCHENS



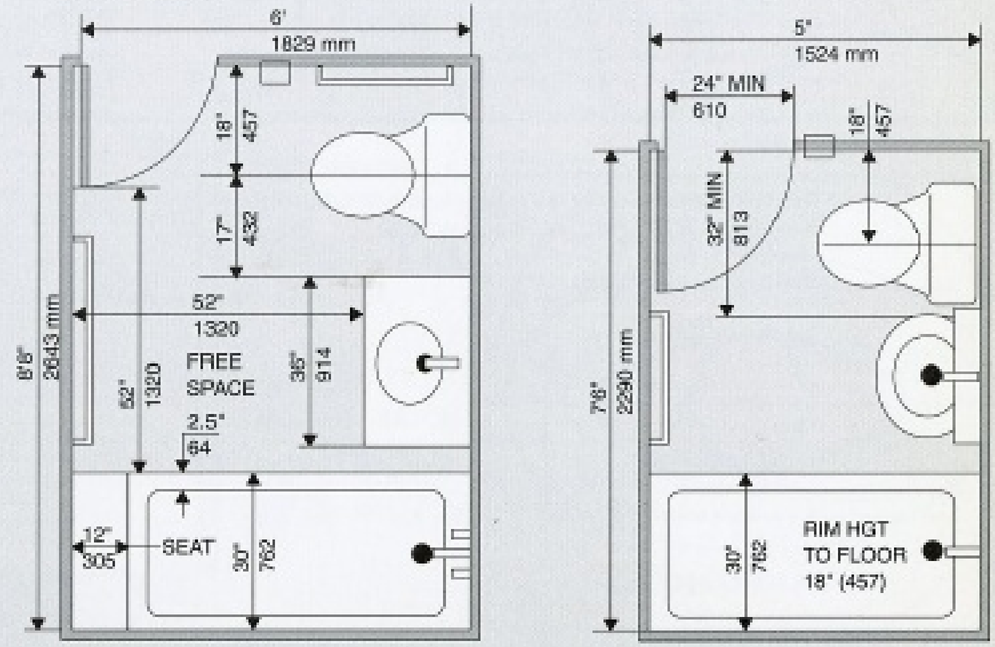
"U" SHAPE KITCHENS



"L" SHAPE KITCHENS



BATHROOMS



MAINTENANCE ACCESS

THE WHOLE BODY

In the drawing, the control panel is sectioned for determining heights for working in three postures: standing, kneeling, and sitting. Note the optimum work angles between the shoulder and the elbow; measurements can be varied 4–6" (101–152 mm) above the shoulders and below the elbows. Any area above is for displays.

The crawling posture is utilized commonly in maintenance procedures. The prone posture is valuable also; it gives access in the most confined space. A supine posture would require more height because the addition of a wheeled carriage (dolly) would be necessary.

Add 5.5" (140 mm) to any of the postures. The minimum width is 24" (610 mm).

On the right is an illustration representing various hatches. The small rectangular hatch and the minimum oval hatches are for horizontal (both overhead and underfoot) access. The large side hatch and the 30"-diameter (760 mm) hatch are for vertical (e.g., wall-mounted) openings.

On chart #43, the grids in the top row define 15 body-access openings, with minimum, preferred, and maximum values given. It is preferable to have the bottom edge of the opening coincident with the floor. The minimum values accommodate the large man with average clothes, the preferred values are military data, and the maximum will accommodate men in arctic clothing.

THE APPENDAGES

Specifications for openings for the hands are shown in the middle section of grids. Each opening has three values: one for bare hands, one for gloves, and one for arctic gloves. There are six openings for a single hand and two for a pair of hands.

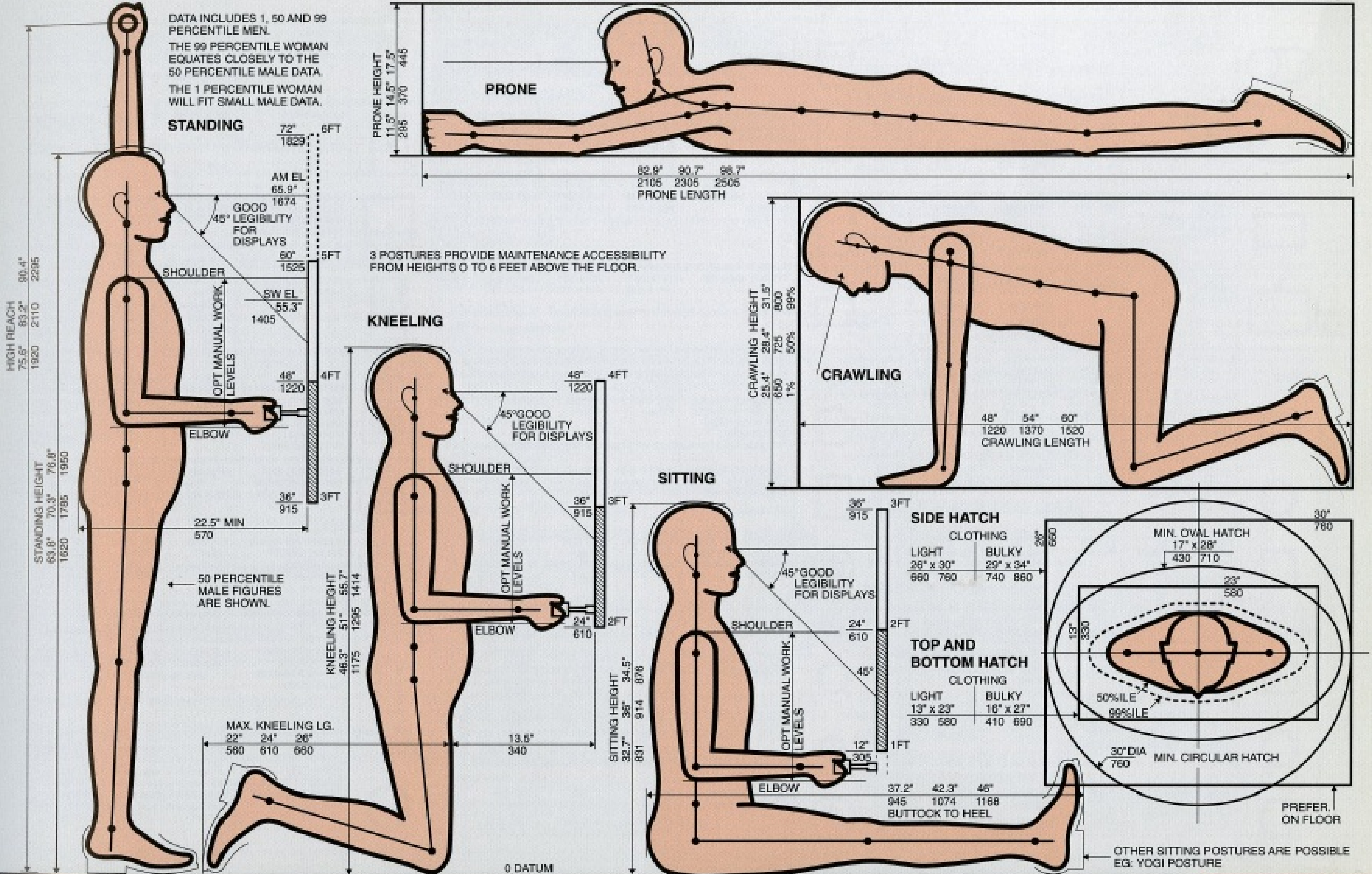
The lower left section has three arm openings without visual access. They are for bare arms, normally clothed arms, and arctic-protected arms.

There are three finger openings, with minimum, bare, and gloved specifications. The first opening admits all normal fingers. The second—a recess for push buttons—excludes the thumbs. The last one is unique in that the finger size is given, but the size of the object must be added. For example, if the object is a recessed knob of 1.25" (32 mm)-diameter, this space must be added to the 1" (25.4 mm) minimum finger clearance, which will then require a 3.25" (82.6 mm)-diameter recess to operate the knob.

Foot openings are required for a bare foot, one wearing a shoe, and one clothed in arctic gear. Here must be added space for clearance around the foot—perhaps 1" (25.4 mm) for the length and 1" for the width.

Openings for bare, military-helmeted, and work-helmeted heads are shown. The first opening, for the bare head, is for the 99 percentile and shows a 0.50" (12.7 mm) clearance on each side. The second gives a military diameter with 0.50" clearance front and back. The third admits a work helmet and also has a 0.50" clearance front and back.

The data and drawings in this section have been adapted from Humanscale 7/8/9, *1981, and* Woodson, *1981.*


DATA INCLUDES 1, 50 AND 99 PERCENTILE MEN.
THE 99 PERCENTILE WOMAN EQUATES CLOSELY TO THE 50 PERCENTILE MALE DATA.
THE 1 PERCENTILE WOMAN WILL FIT SMALL MALE DATA.
STANDING
72" 1829 6FT
AM EL 65.9" 1674
GOOD 45° LEGIBILITY FOR DISPLAYS
60" 1525 5FT
SHOULDER
SW EL 55.3" 1405
OPT MANUAL WORK LEVELS
48" 1220 4FT
ELBOW
36" 915 3FT
22.5" MIN 570
50 PERCENTILE MALE FIGURES ARE SHOWN.
HIGH REACH 75.6" 83.2" 90.4" 1920 2110 2295
STANDING HEIGHT 63.8" 70.3" 76.8" 1620 1785 1950
PRONE
PRONE HEIGHT 11.5" 14.5" 17.5" 295 370 445
82.9" 90.7" 98.7" 2105 2305 2505 PRONE LENGTH
3 POSTURES PROVIDE MAINTENANCE ACCESSIBILITY FROM HEIGHTS O TO 6 FEET ABOVE THE FLOOR.
CRAWLING
CRAWLING HEIGHT 25.4" 28.4" 31.5" 650 725 800 1% 50% 99%
48" 54" 60" 1220 1370 1520 CRAWLING LENGTH
KNEELING
48" 1220 4FT
45°GOOD LEGIBILITY FOR DISPLAYS
SHOULDER
OPT MANUAL WORK LEVELS
36" 915 3FT
24" 610 2FT
ELBOW
KNEELING HEIGHT 46.3" 51" 55.7" 1175 1295 1414
MAX. KNEELING LG. 22" 24" 26" 560 610 660
13.5" 340
0 DATUM
SITTING
36" 915 3FT
45°GOOD LEGIBILITY FOR DISPLAYS
SHOULDER
24" 610 2FT
45°
OPT MANUAL WORK LEVELS
12" 305 1FT
ELBOW
SITTING HEIGHT 32.7" 36" 34.5" 831 914 876
37.2" 42.3" 46" 945 1074 1168 BUTTOCK TO HEEL
SIDE HATCH
CLOTHING
LIGHT 26" x 30" 660 760
BULKY 29" x 34" 740 860
26" 660
30" 760
MIN. OVAL HATCH 17" x 28" 430 710
23" 580
13" 330
TOP AND BOTTOM HATCH
CLOTHING
LIGHT 13" x 23" 330 580
BULKY 16" x 27" 410 690
50%ILE
99%ILE
30"DIA 760
MIN. CIRCULAR HATCH
PREFER. ON FLOOR
OTHER SITTING POSTURES ARE POSSIBLE EG: YOGI POSTURE

BODY

BODY	MINIMUM	PREFER	MAXIMUM
CIRCULAR HATCH OR MANHOLE FOR TOP AND BOTTOM ACCESS	23" DIA 585mm AVERAGE CLOTHES AIRCRAFT	30" DIA 760mm MIL MIN	40"DIA 960mm BULKY CLOTHES ARCTIC OR SPACE
CRAWL THROUGH PIPE OR TUNNEL	28" DIA 711mm	30" DIA 760mm MIL SPEC	40" DIA 960mm FOR ARCTIC
OVAL HATCH TOP AND BOTTOM ACCESS	17" x 28" 430 x 710	17" x 28" 430 x 710 MIL SPEC ARMORED VEHICLES	N A
RECTANGULAR HATCH TOP AND BOTTOM ACCESS	20" x 24" W 580 x 610 IF FROM STAIR LADDERS	13" x 23" W 330 x 585 MIL SPEC LIGHT CLOTHES	16" x 27" W 410 x 690 MIL SPEC BULKY CLOTHES
RECTANGULAR HATCH SIDE ACCESS	17" x 28" W 430 x 710	26" x 30" W 660 x 760 MIL SPEC LIGHT CLOTHES	29" x 34" W 740 x 860 MIL SPEC BULKY CLOTHES

HAND

HAND	BARE	GLOVES	ARCTIC
EMPTY HAND HELD FLAT TO WRIST WITHOUT VISUAL ACCESS	2.25" x 4.0" 55 x 100mm	4.0" x 6.0" 100 x 150 ALSO WITH MITTEN	5.0" x 6.5" 125 x 165
ROLLED HAND ACCESS TO WRIST WITHOUT VISUAL ACCESS	3.75" DIA 95mm	5.75" DIA 146mm	6.25" DIA 159mm
ROLLED HAND ACCESS TO WRIST WITHOUT VISION (ALTERNATE)	3.5" SQ 89mm	5.5" SQ 140mm	6.0" SQ 152mm

ARM

ARM	BARE	CLOTHED	ARCTIC
ARM TO ELBOW WITHOUT VISUAL ACCESS (ALTERNATE)	SAME AS LIGHT CLOTHING	4.0" x 4.5" 100 x 115 LIGHT CLOTHING	6.6" x 7.1" 168 x 180
ARM TO ELBOW SQUARE OR ROUND WITHOUT VISUAL ACCESS	SAME AS LIGHT CLOTHING	4.5" DIA 115mm	7.1" DIA 180mm
ARM TO SHOULDER SQUARE OR ROUND WITHOUT VISUAL ACCESS	SAME AS LIGHT CLOTHING	5.0" DIA 125mm LIGHT CLOTHING	8.5" DIA 215mm

BODY

BODY	MINIMUM	PREFER	MAXIMUM
AIRCRAFT SIDE HATCH TO ESCAPE WITH PACK	31" x 22" W 790 x 560	32" x 24" W 815 x 610 TO INCLUDE 99%ILE MAN	50" x 40" W 1300 x 960 WITH'A' =18" 457 mm
AIRCRAFT BELLY HATCH TO ESCAPE WITH PACK	29" x 22" W 740 x 560	30" x 22" W 760 x 560 INCLUDES 99%ILE MAN	50" x 40" W 1300 x 960
WATER TIGHT AND ARMORED HATCHES	62" x 22" W 1600 x 560 WITH 'A' = 16" MAX 410mm TO DECK	68" x 24" W 1730 x 610 WITH 'A'=10" 255mm TO DECK	50" x 40" W 1300 x 960 WITH'A' =18" 457mm TO DECK
CRAWL THROUGH ACCESS	31.5" x 24" 800 x 610	36" x 30" 915 x 760	NO MAX
PRONE ACCESS	18" x 23" 460 x 585	20" x 30" 510 x 760	24" x 30" 610 x 760

HAND

HAND	BARE	GLOVES	ARCTIC
CLENCHED HAND ACCESS TO WRIST ADD VIEW AREA AS REQUIRED	5.0" DIA 125mm	6.0" DIA 150mm	8.5" DIA 215mm
CLENCHED HAND ACCESS TO WRIST ADD VIEW AREA (ALTERNATE)	3.75" x 5.0" 95 x 125mm	4.5" x 6.0" 115 x 150	7.0" x 8.5" 180 x 215
INSERTING 1" DIA OBJECT TO WRIST WITHOUT VISUAL ACCESS	3.75" DIA 95mm OR SQUARE	6.0" DIA 150mm OR SQUARE	7.0" DIA 180mm OR SQUARE

FINGERS

FINGERS	MINIMUM	BARE	GLOVES
PASSES ALL SINGLE FINGERS IF HEALTHY	1.25" DIA 32mm ACCESS HOLE	1.25" DIA 32mm ACCESS HOLE	1.50" DIA 38mm ACCESS HOLE
RECESSING PUSH BUTTONS	1.0" DIA 25.4mm OMITTING THUMB USE	1.25" DIA 32mm INCLUDES THUMB USE	1.50" DIA 38mm INCLUDES THUMB USE
TWIST ACCESS TO FIRST JOINT	2" DIA 50mm ADD SIZE OF OBJECT	2" DIA 50mm ADD SIZE OF OBJECT	2.5" DIA 65mm ADD SIZE OF OBJECT

BODY

BODY	MINIMUM	PREFER	MAXIMUM
CATWALK OR TUNNEL ADD FOR BULKY EQUIPMENT	H=63"(1600) C=25"(635) F=12"(305) MUST STOOP	H=78"(1980) C=25"(635) F=16"(305) CAN STAND	H=80"(2030) C=28"(710) F=19"(480) SPACE FOR HANDRAIL IF VEHICLE
SIDEWAY PASSAGES	78" x 14"W 1980 x 355	80" x 16"W 2030 x 405	84" x 24" W 2130 x 610
DOORWAYS	78" x 24"W 1980 x 610	80" x 30"W 2030 x 760	84" x 36"W 2130 x 915
SPACE REQUIRED FOR TWO PERSONS WALKING ABREAST THROUGH OPENING	80" x 44"W 2030 x 1120	84" x 54"W 2135 x 1370	96" x 60" 2440 x 1525 PERMIT PERSON TO PASS WITH CHAIR
WHEELCHAIR CLEAR ACCESS	32"W MIN 815mm BETWEEN OPENED DOOR AND JAMB	36"W MIN 915mm BETWEEN TWO WALLS	60"D MIN 1525mm TO TURN 360 DEG ON FLOOR

HANDS

HANDS	BARE	GLOVES	ARCTIC
ONE HAND GRASPING OBJECT GREATER THAN 1"(25.4mm) PASS TO WRIST	W=5.0" MIN 125mm H PLUS 3.5" 90mm	W=6.0" MIN 150mm H PLUS 5.0" 125mm	W=6.5" MIN 165mm H PLUS 7.0" 180mm
INSERTING BOX WITH HANDS ON SIDE TO WRIST	W PLUS 3.5" 90mm H= 5.0" MIN 125mm	W PLUS 5.0" 125mm H= 6.0" MIN 150mm	W PLUS 7.0" 180mm H= 6.5" MIN 165mm
TWO HAND REACH TO 12" DEPTH 305mm WITHOUT VISION	4.5" HIGH 115mm 12" WIDE 305mm	5.0" HIGH 125mm 12" WIDE 305mm	7.0" HIGH 180mm 15" WIDE 380mm

FOOT

FOOT	BARE	SHOE	ARCTIC
AREA REQUIRED FOR A FOOT ADD CLEARANCE AS NEEDED	4.5" x 11.7" 114 x 298	5" x 13" 127 x 330	6.3" x 15.3" 160 x 389

HEAD

HEAD	BARE	HELMET	HELMET
CIRCULAR OPENING TO PASS HEAD INCLUDING THE NOSE	11" MIN D 280 mm INCLUDES 0.50" CLEAR 12.7mm	MILITARY 14" DIA 356mm 0.50" CLEAR 12.7mm	WORK 14" DIA 356mm 0.50" CLEAR 12.7mm

SAFETY AT WORK AND AT HOME

Safety is a basic human need. Human factors does more than increase machine efficiency and profits; it also conscientiously considers the safety and comfort of human beings. The following terms define safety categories:

Inherently safe: Human error will not degrade, damage, be a hazard, or cause injury.

Marginally safe: Human error could result in injury.

Dangerous: Human error is likely to cause injury or death.

Catastrophic: Human error can cause severe degradation—loss of system, injuries, death, or multiple deaths.

Safety is the concern of all designers, who should investigate and eliminate all hazards and attempt to make all conditions inherently safe. Some engineers consider the potential for human error to be so great that it is impossible to anticipate every mistake that can lead to harm. Nevertheless, the designer should consider how errors can develop and try to envision scenarios in which damage to people and equipment can occur.

A pragmatic approach is to review the following safety checklists for the factory, the office, and the home.

FACTORY

This list cannot include all the hazards in every field of endeavor, but the items listed will help identify hazards. (These are from *Humanscale 4/5/6*, 1981.)

- Have all rotating devices been equipped with protective guards?
- Are the face and eyes protected by guards against emissions and sparks?
- Has protection been provided to keep personnel from being rammed or pinched by reciprocating parts?
- Are the fingers or hands protected with clearance between cutting and trimming parts?
- Have sharp edges and burrs been eliminated?
- If an emergency "stop" button is required, is it strategically located?
- Are critical controls guarded to prevent inadvertent operation?
- Are hazard warnings precise and conspicuous?
- Are controls accessible?
- Are safety interlocks available to protect operators?
- Can monitoring devices help?
- When an unsafe threshold is reached, does the operator know how to respond?
- Is it safe to operate the product in extreme temperatures and high humidity?
- Is it safe to use a product that has encountered shock and vibration?
- Is it possible to reassemble a product in such a way that it will become unsafe?
- Can a discarded unit be safely buried or recycled without emitting toxic fumes or causing pollution?
- Are lifting handles comfortable and at a safe temperature for handling?
- Are components light enough to carry without risk of physical injury?
- Has protection been provided for personnel who may accelerate or decelerate rapidly?
- Is illumination adequate for detecting hazards in all areas?
- Has protection from bright light (intense flashes, welding arcs, etc.) been provided?
- Has protection against radiation (microwaves, lasers, etc.) been provided ?
- Have all precautions been taken to avoid electrical shock? (Even a small shock can cause a secondary accident.)
- Have noise levels been reduced to meet standards to prevent hearing loss? Has the noise level been reduced to prevent fatigue and interference with hearing?
- Are temperature and control maintained within human tolerance?
- Have toxic substances been avoided?
- Has thought been given to the prevention of fires and explosions?
- Have tripping hazards been eliminated?
- Have slipping hazards been eliminated?
- Do low overhead clearances exist?
- Are guardrails and safety belts adequate to reduce the possibility of falling?
- Has an appropriate safety checklist been prepared for a specific plant and product?
- Have safety placards and a safety program been created?

Noise, temperature, and illumination are major topics and appear in the section entitled "Environment."

OFFICE

This broad topic is confined here mostly to the use of computer work stations. First, consider the seat for a computer operator. It should have sufficient adjustability to permit a comfortable posture while working.

- The seat height should adjust vertically from 14.5" (370 mm) to 19.5" (495 mm) to accommodate all workers. Adjust the seat height so that the front edge carries no load.
- If the chair has a backrest, its height should be:

  25" (635 mm) for shoulder support.

  36" (915 mm) for head support.

  15.7" (400 mm) for arm reach-over.
- Up-and-down lumbar support adjustment should be 4" (100 mm); an in-and-out adjustment of 2" (51 mm) minimum is needed.
- Upholstery should provide comfort, friction, and ventilation. Avoid coarse fabrics.
- Armrests should be 2–3.5" (51–89 mm) wide and 10" (254 mm) forward of the seat reference point. These may be padded softly.
- The chair should swivel and have 5 or 6 feet.

  See also the section entitled "Seating."

Computer Consoles

Refer to the charts entitled "Computer Stations for Men and Women" and examine the 1 to 99 percentile women working at a computer. Note that the keyboard is movable and can be angled, and the monitor is rotatable, vertically adjustable, and tiltable to minimize reflections.

Operators today prefer the erect posture for short work periods or a more relaxed posture for longer durations. The following items are important:

- Table height is adjustable 23–29" (585–735 mm) for women only.
- Examine the console for the 1 to 99 percentile man working at a computer.
- Table height is adjustable 25–31" (635–785 mm) for men only.
- An alternate design is a fixed table height of 28.25" (720 mm) for all adult men and women.
- A separate shelf required for the keyboard must travel from 23 to 28.25" (585–720 mm) and must be large enough for using a mouse.
- To prevent Carpal Tunnel Syndrome always try to keep hand and forearm in a nearly straight line deviating less than 5°. Operators should take frequent rest periods.
- New keyboards, split in the middle and angling each half to match the hand position, should improve comfort.
- To avoid electromagnetic fields, keep the cathode-ray tube (monitor screen) at an arm's lenght away. The operator should maintain a distance of 48" (1219 mm) from the sides or back of another terminal.
- The office environment should be pleasant.

HOME

Stairs are the location of the highest number of accidents in the home, but bathrooms, windows, doors, kitchens, floors, electrical systems, exteriors, and additional considerations are also discussed. Unless otherwise noted, the recommendations summarized for safety in the home are taken from the design guide published by the U.S. Department of Housing and Urban Development, 1972.

Stairs

Of course, slippery stairs must always be avoided, either by carpeting or applying high-friction surfacing to inordinately smooth stair surfaces. Stair design should take the following items into account:

- Exterior stairs should pitch forward 1/8" (3.2 mm). Consider broom-finished concrete or bricks to provide friction.
- Optimum interior stairs have a maximum rise of 7.5" (190 mm), a minimum run of 10" (254 mm), and a minimum tread of 11.25" (286 mm). The maximum nose is 1.25" (32 mm).
- Exterior stairs for a building should have a maximum rise of 6" (152 mm), a minimum run of 11" (279 mm), and a minimum tread of 12" (305 mm). The maximum nose is 1" (25.4 mm).
- Exterior stairs unattached to a building should have a maximum riser height of 5" (127 mm), a minimum run of 14" (355 mm), and a minimum tread of 15" (381 mm).
- To reduce stair accidents, keep risers and treads within a 0.188" (4.8 mm) margin of error.
- Avoid single risers inside or outside the house. Exception: if one riser at the front door is possible, this is acceptable.
- Use the following rules to determine step variations:

  1 rise + 1 run = 17–18" (431.8–457.2 mm)

  2 rise + 1 run = 24–25" (609.6–627 mm)

  1 rise x 1 run = 70–75" (17,780–19,050 mm)
- Do not exceed 16 risers in any straight run; a landing after every 8 risers, for a rest period, is preferable.
- Place light switches at the top and bottom of staircases.
- Avoid sharp edges.
- Handrails are usually on the outboard side. Prefer a 42" height (1067 mm) on balconies. Prefer 30–40" (711–864 mm) above the nose and for porches.
- If the stairway width is 40" (1016 mm), add a railing to the fixed wall also.
- Never allow any opening in a staircase structure—e.g., under the nose—to exceed 4.5" (114 mm); otherwise, a child's head could pass through the opening and get caught. In general, avoid open staircases to protect children and adults who might slide their feet too far forward.
- Avoid locating doors near the steps.
- A front porch entry should be wide, to allow for room around and in front of the door, particularly when it swings outward.

Bathrooms

To prevent injury to the bather, it is best to provide the floor of the tub or shower with a nonskid surface. Another important consideration is the exclusive use of safety glass on all glass shower doors. The following specifications for bath fixtures and layout are provided with safety in mind:

- Faucets in bathtub/shower combinations should be mounted at a height of 30–34" (762–864 mm), measured from the tub floor.
- Controls for showers alone should be at 48–52" (1219–1321 mm), measured from the tub or shower floor.
- Provide a towel bar about 6" (152 mm) from the exit from the tub or shower.
- Install two horizontal grab bars 18" (457 mm) long on the center of the long wall, one at 32–36" (813–914 mm) and the second one at an additional 12" (305 mm) above that.
- Locate an inset soap tray, centered, several inches below the low bar.
- The shower head clearance to the tub bottom should be 69–72" (1753–1829 mm).
- The shower-curtain rod should be 72–78" (1829–1981 mm) from the tub floor. Keep the rod inside the tub area.
- The faucets and one grab bar should be located 42–48" (1067–1219 mm) above the floor. Locate the faucets inside the shower, near the entrance.
- On shower doors, avoid the use of latches, which can pinch, gouge, cause scrapes, etc.
- The shower should have a vapor-proof light fixture, centered, with the switch 72" (1829 mm) away from stall.
- Avoid sharp edges on all grab bars. The tube can have a comfortable, unslippery texture.

- The toilet requires a space of 36" (914 mm) between two walls, or a space of 32" (813 mm) between one wall and a bathroom fixture.
- Provide one lavatory cabinet 36" (914 mm) long.
- The tub should be 60" (1524 mm) long. There should be a 12" (305 mm) seat built at the end that is opposite the water faucet.
- The minimum floor space is 30 x 42" (762 x 1067 mm). The preferred floor space is 42 x 72" (1067 x 1829 mm) for towel-drying movements.
- For privacy and safety, the window sill should be 48" (1220 mm) above the floor
- The bathroom door should be a minimum 24" (610 mm) wide and should swing against a wall or the tub.
- Accommodations for the differently abled persons are detailed on the illustration.

Windows

The use of safety glass, which minimizes accidents, should always be a consideration. For safety reasons the following recommendations are given:

- The crank-operated sash is preferable to the double-hung sash, in which loose-fitting windows can slide down, causing injury to head and hands. Casement windows, some of which can be cleaned from inside, are advantageous.
- Projecting windows are possible, if crank-operated.
- Picture windows are hazardous unless they are made from high-impact-resistant safety glass. As an alternative, use a minimum sill height of 30–36" (762–914 mm).

Doors

Safety glass minimizes accidents, especially around children. Solid doors with rounded edges are preferable. Moreover, glass and ceramic door knobs should be avoided; if fractured, they can cause serious injuries. Consider lever knobs for more hand clearance and better leverage. Other important considerations follow:

- Avoid two-way swinging doors in residential housing.
- Avoid two doors that swing in conflict with one another.
- For a full opening, doors should swing into a room against a wall or open at least 90°.
- The head of a stairway should not be located next to or opposite a frequently used door.
- Door widths of 30–32" (762–813 mm) should be used for interior doors, 36" (915 mm) for outside doors. Widths of 24" (610 mm) should be used only in bathrooms.
- Garage doors made of sections can cause severe finger crushing. Place grab bar handles on the lower sections near the center.
- Make garage door width a minimum of 9 ft (2745 mm), even though 8 ft (2439 mm) is the standard. This gives more room for entry and exit.
- Make the garage larger to include a workshop, if desired; allow 30" (762 mm) for any passageway..
- Two 9-ft (2646 mm) doors are better than one large door.
- Provide garage illumination of 30 footcandles (325 lux) in general areas and at least 70 fc (753.5 lx) over a workbench area.
- Provide ample electrical outlets, to lessen the need for extension cords.
- Provide ventilation and heat if the garage is used as a workshop.

Kitchens

Large kitchens are not necessarily more efficient or safe. Consult the chart "Residential Space Considerations" for recommended location of range and sink. The following is a guide to planning safe kitchens:

- All edges in a kitchen should be rounded.
- A safe kitchen has a small triangle from refrigerator to sink to stove to refrigerator. The sum of the three sides of this work triangle is under 23 ft (7010 mm). The triangle should not be interrupted by traffic flow.
- An aisle 48" (1219 mm) wide is the minimum in a U-shaped kitchen.
- Kitchen cabinets are 36" (915 mm) standard height and 24" (610 mm) deep. Wall cabinets are a minimum of 15" (381 mm) above the kitchen cabinets. They are 12" (305 mm) deep, and the highest shelf is 72" (1829 mm) above the floor.
- Provide illumination of 70 fc (753.5 lx) over the sink and 50 fc (538 lx) over counters.

Floors

Carpets on floors are a safety improvement. Area rugs should be placed on a nonskid material underlay. Floors can be covered with stones, brushed concrete, tiles that are not slippery, and so on, to minimize slipping accidents.

Electrical Safety Considerations

Everything in the planning of a home must follow the building code of that area, and that, of course, includes the electrical wiring. Some other concerns include the following:

- Lighting fixtures should be at least 80" (2032 mm) above the floor, unless located over a table.
- Keep switches as far from water fixtures as possible.
- Provide a duplex receptacle for each 4 feet (1219 mm) of work surface.

There should be one of these for each refrigerator and dryer, one for ironing, and one for a work surface in the kitchen. Self-tripping outlets for kitchen and bath are recommended.

Yards and Walkways

Avoid slopes that are graded steeper than 10°; it is dangerous to mow steeper grades. Planting ground-covering plants on steep slopes is advised. Other safety considerations follow:

- Avoid use of walls from which children can fall, or install fencing or shrubbery along a wall's top edge as a safeguard.
- A walkway 24" (610 mm) wide is good for men or women; a 30" (762 mm) walk is good for a child on a tricycle; and a 36" (915 mm) walk is good for a person pushing a stroller or a dolly.
- Avoid single outside steps; prefer two or three as optimum.
- Walking surfaces should have texture. Brush concrete surfaces, or cement bricks to the concrete slab and grout well.

- Do not make curves too sharp.
- Ladder access to all windows should be possible in the yard, for cleaning purposes.
- The minimum driveway width is 10 feet (3048 mm). Exit 90° to road, cutting through curb.
- Locate drainage inlets away from traffic. Openings in sidewalk vents (grids), drains, etc., should be too small to admit high-heeled shoes, bicycle tires, or rodents.
- The following plants have poisonous properties and thus may not be appropriate around children: Autumn Crocus, Star of Bethlehem, Azaleas, Black Locus, Bleeding Heart, Buttercups, Castor Bean, Daffodil, Daphne, Dieffenbachia, Elderberry, Elephant Ear, Foxglove, Golden Chain, Hyacinth, Iris, Jack-in-the-Pulpit, Jessamine, Jimson Weed, Lantana Camara, Larkspur, Laurel, Mayapple, Mistletoe, Monkshood, Moonseed Daffodil, Nightshade, Oleander, Poinsettia, Poison Hemlock, Poison Ivy, Poison Oak, Rhododendron, Rosary Pea, Water Hemlock, Wild and Cultivated Cherry, Wisteria, and Yew.

Swimming Pools

Installing a 72" (1829 mm) fence all around the pool is advised for maximum safety. A chain-link, or diamond, fence may be prefered, but remove any sharp points and lash the netting to the horizontal pole. The gate height should be the same, with the latch 48" (1219) above ground level. If the 72" (1829 mm) pool fence connects to a building, install a 48" (1219 mm) fence between the pool and the building. If the local building code exceeds these recommendations, follow the code. Also take the following items into account:

- Provide good illumination and equipment. Leave a 25-ft (7620 mm) distance between the pool and switches (indoors).
- A diving board should face north, northwest, or northeast to prevent eyestrain. For maximum safety, keep the board height at deck level.
- Prefer a rectangular pool. Texture it all over to prevent slipping.
- Provide a "shepherd's crook," floats, and lines. Also provide for keeping a first-aid kit accessible near the pool.

Children's Safety

The dimensional information outlined below was obtained from the Code of Federal Regulations published by the U.S. Consumer Product Safety Commission, 1989.

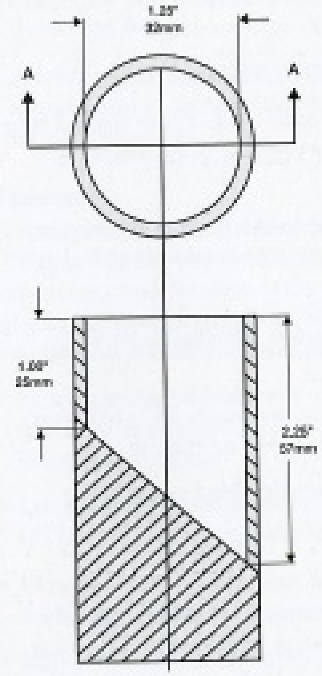
No toy or article (or part of an article) should be small enough to fit entirely within a cylinder of the dimensions illustrated. No portion of a rattle should be capable of entering and penetrating to the full depth of a cavity in a test fixture with these dimensions. And no pacifier should be capable of being pulled through the opening of a fixture with these dimensions while applying a 2-pound force. Other safety recommendations include the following:

- Toys should have integral colors, rather than a paint or other coating that can peel or flake off.
- Strings or flexible cords longer than 12" (3048 mm) on pull toys for children younger than age 3 should not be provided with beads or other attachments that could tangle and form a loop.
- Flexible cords attached at one end to a toy intended for use in cribs and playpens should be less than 12" (3048 mm) long. If a cord forms a loop, then the perimeter of the loop must be less than 14" (3556 mm).
- This drawing shows recommended dimensions for a full-size crib.

Also consider the following when designing products or environments for children:

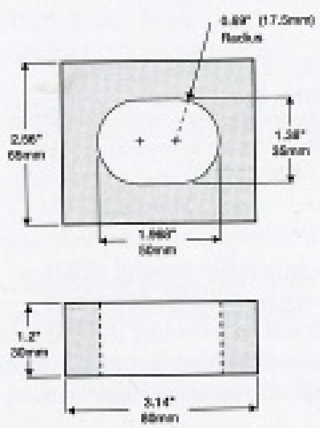
- Children often have safety problems with windows.
- Children get hurt if a door is swung against them, and they can get fingers pinched between the sill and the door, on both the hinged and the latching edge of the door.
- Nonskid (textured) floor materials are best.
- Avoid the use of lead-content paints.
- Provide for keeping medicines, chemicals, poisons, and flammable materials out of children's reach.
- Do not put objects that can be swallowed within the reach of children.
- Anticipate situations in which children can be hurt on bicycles or tricycles (steep slopes, hard surfaces, etc.).

SMALL PARTS GAUGE
Section A-A

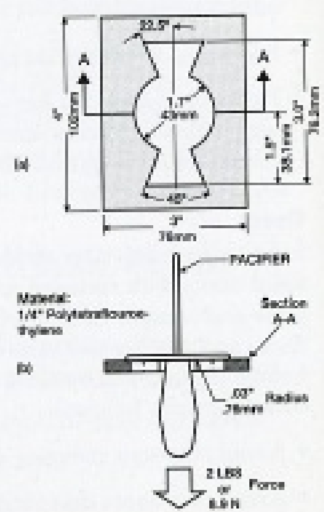


RECOMMENDED FULL SIZE CRIB DIMENSIONS

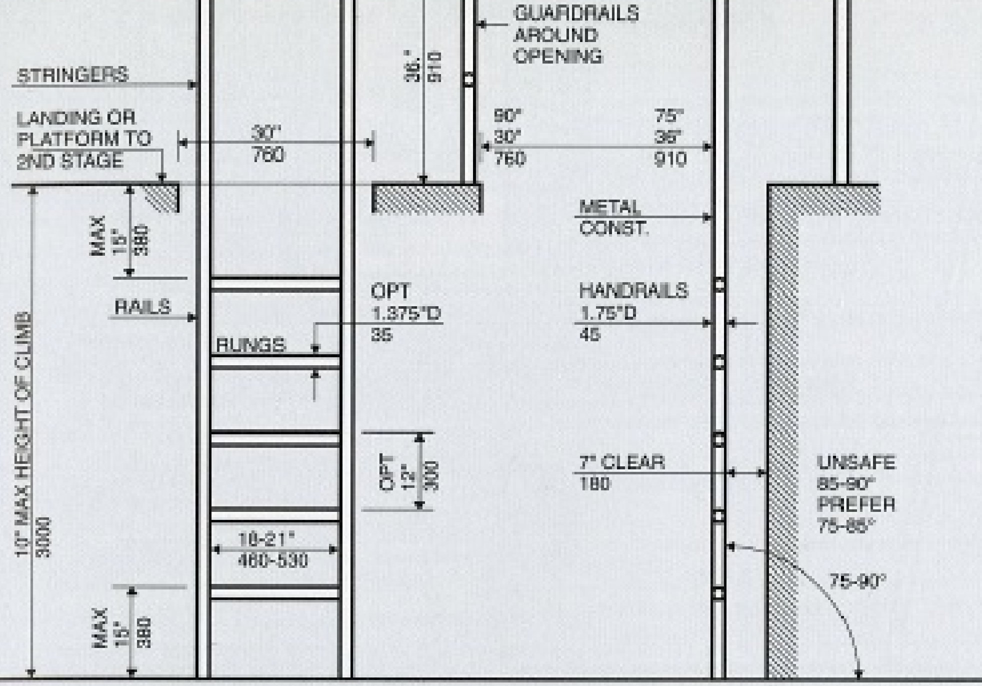
RATTLE TEST FIXTURE



PACIFIER TEST FIXTURE



FIXED VERTICAL LADDERS



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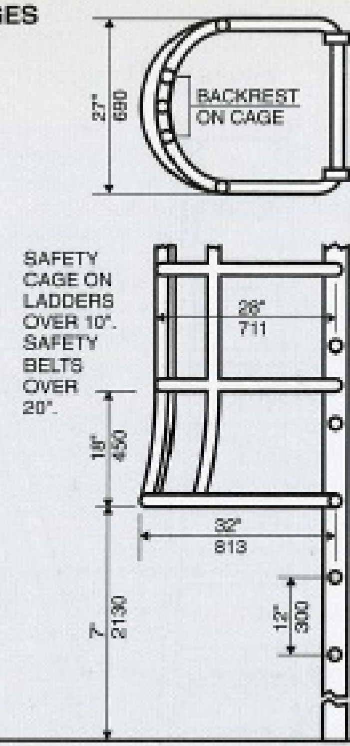
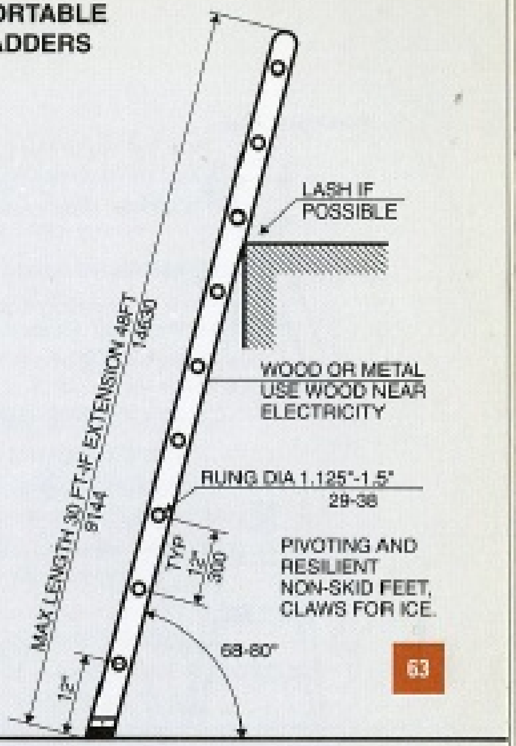


PORTABLE LADDERS



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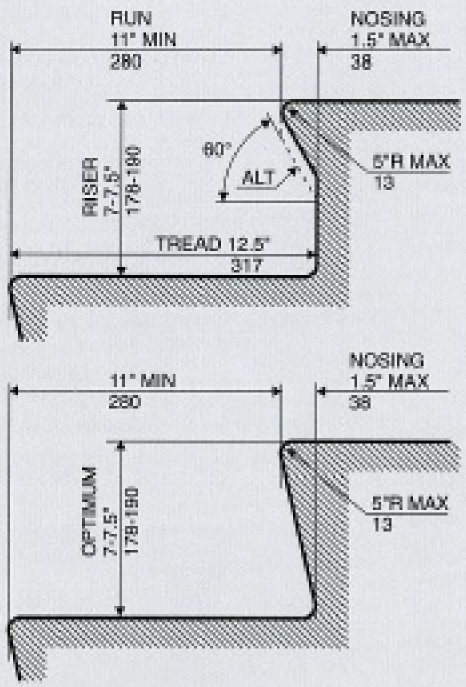
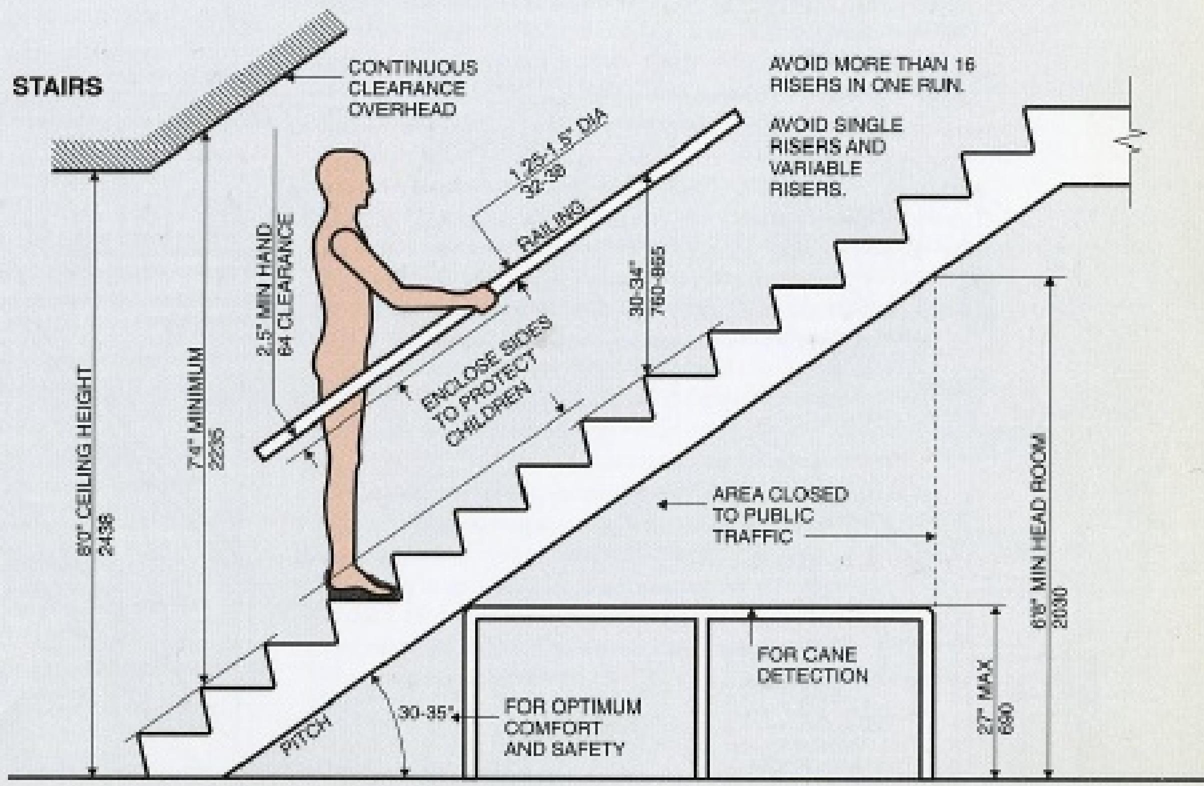
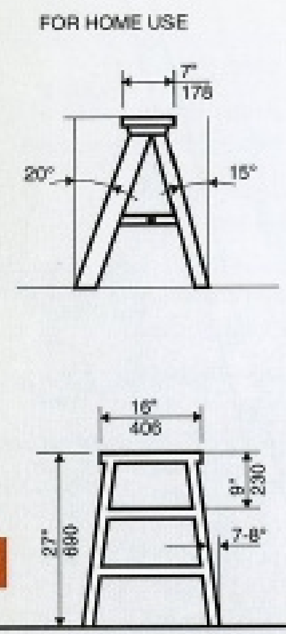
INTERIOR STEPS

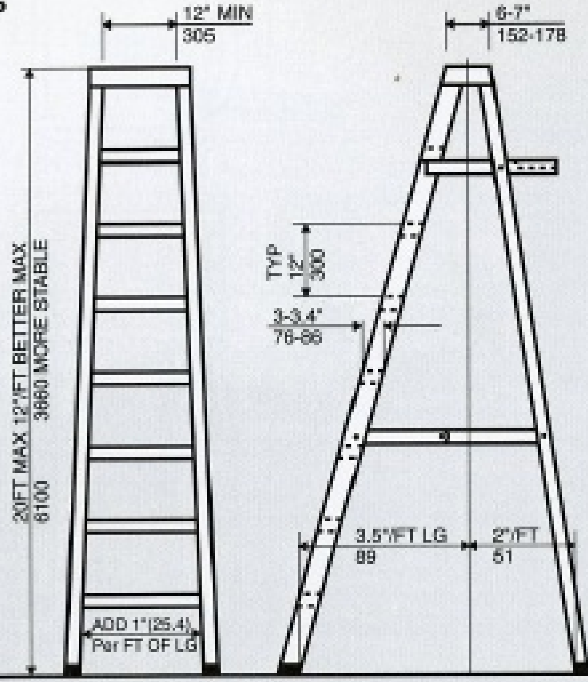


STAIRS

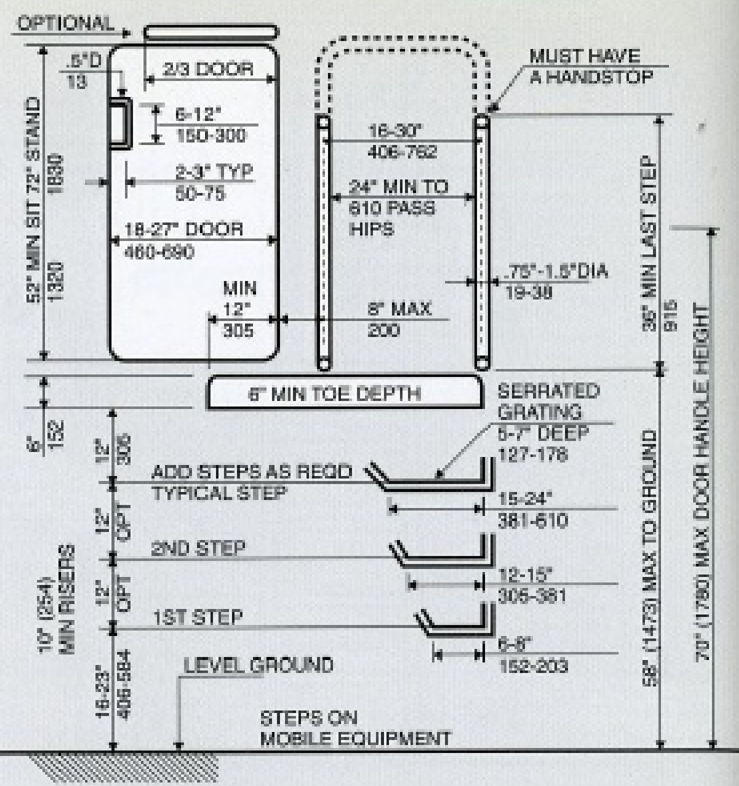


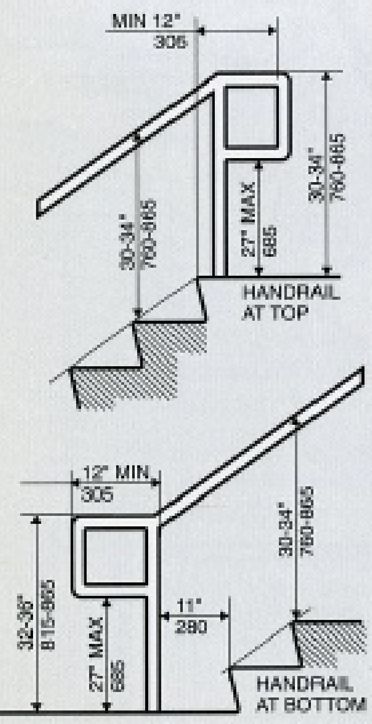
STEP LADDERS



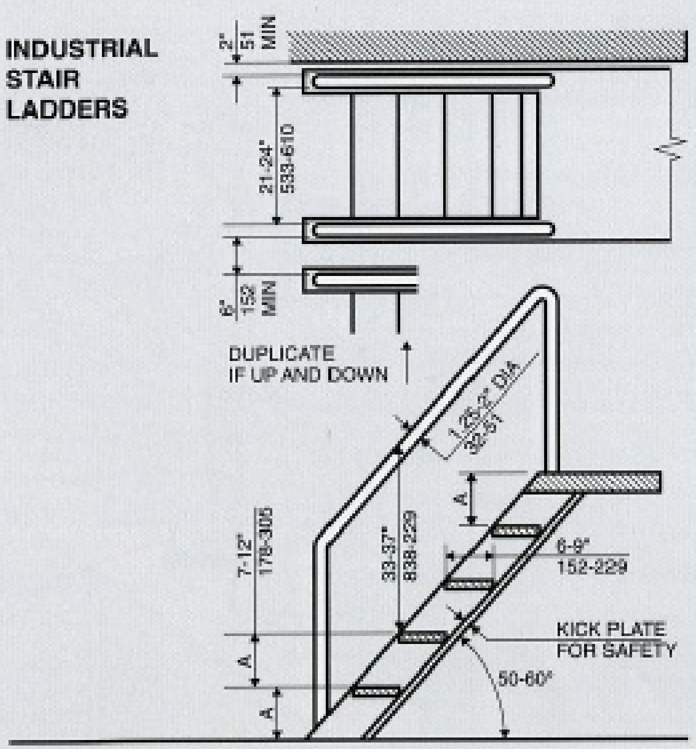


STEP-ON MOBILE EQUIPMENT



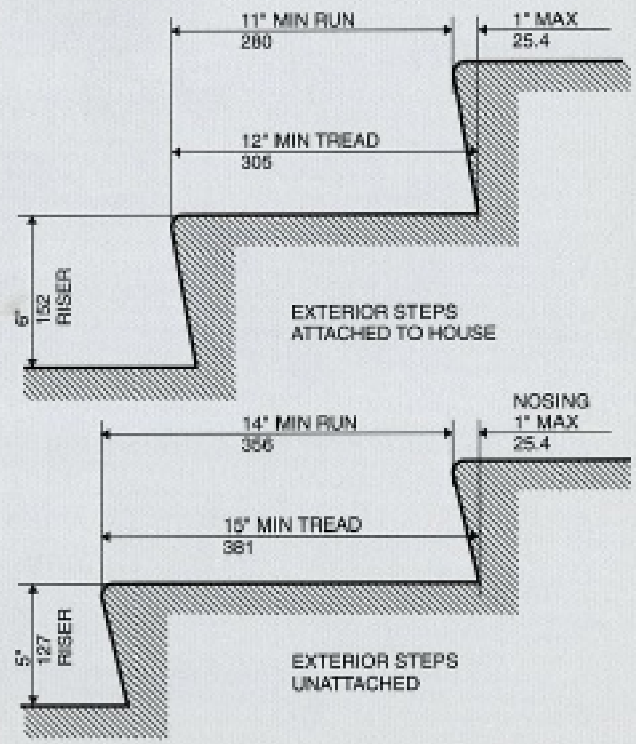


INDUSTRIAL STAIR LADDERS



EXTERIOR STEPS

LIMIT STEP ERRORS TO A TOLERANCE OF .2" (5mm) TO REDUCE ACCIDENTS



VEHICULAR ACCOMMODATION

CONSTANT FACTORS IN VEHICULAR SEATING

The information under "Constant Factors in Vehicular Seating" should also be consulted for the needs of people in vehicles. Note that the given seating posture is only for the driver; passengers may prefer a greater seat/backrest angle. The 1 percentile small female driver and the 99 percentile large male driver are shown in the alert posture.

This diagram shows the human figures with optimum ankle angle, optimum knee angle, and optimum spine and upper leg angles for operating a vehicle. They are practically the same for all vehicles; only the floor angle changes for race cars, sports cars, sedans, trucks, vans, buses, industrial equipment, and stationary uses by rotating the floor lines about the same common heel point.

The seats and backrest could be constant for all vehicles. The headrest will change, since the head center line must be perpendicular to the chosen road line.

The vehicle contours will change dramatically: the race car needs low frontal resistance, and agricultural and industrial vehicles need a small front-to-rear direction, since downward visibility is very important, while aerodynamics is not critical.

Steering-wheel diameters vary for different vehicles, and angling the wheel may be an improvement in some cases, to maintain the correct thigh clearance.

- A relaxing ankle angle is 100°, assuming 6–6.5° for the shoe angle. This is a good angle for the resting left foot or for the right foot on the accelerator pedal at the normal cruise speed.
- The knee angle is good at 110–120° for maximum pressure on the pedals. The 120° was chosen because the knee angle becomes less when the leg is raised to brake. Also, the foot can form an angle of 85°, if required. The seat-to-back angle is shown at 95°. The upper leg bone is shown at 3°, so the leg bone and backbone are 98° (95–100° is optimum).
- The headrest must keep the head center line vertical in a race car, a sports car, and an automobile. The headrest should be specially made for the race car driver and have side supports.
- Note the six categories of vehicles with 5° variations allotted to each; these 5° variations can be overridden if required.
- Vertical and forward seat dimensions are given for full seat adjustment at each 5° line.
- The brake-pedal pressure point is shown. Travel may vary depending on the brake system and pressure. Preferable are power-operated brakes to accommodate 98% of the possible work force.

Information from Humanscale 1/2/3, *1974;* Humanscale 4/5/6 *and 7/8/9, 1981; and Purcell, 1980, was used to develop the text and diagrams in this section.*

AGRICULTURAL AND INDUSTRIAL EQUIPMENT

These drawings show the side view of the 99 percentile man and the 1 percentile woman, seated. The second drawing shows the top view of each. The purpose of these layouts was to establish the location of control areas for a tractor-type enclosed vehicle.

The starting point for this type of seating is the heel point: assume a shoe with an approximate heel height of 1.2" (30 mm), which gives a foot angle of 6.5°. In this case, assume the ankle angle to be 96.5°. The knee angle of 110° was chosen to keep the large man small from front to back, because this is the critical dimension. Now the spine was drawn at 100° from the upper leg bone (thigh bone), which is a comfort angle. The human figure was drawn on top of this overlay and rotated until the seat became as high as possible—the front edge is at a height of 19.5" (495 mm) and the seat reference plane is at 17.8" (452 mm). The seat length of 16.5" (419 mm) makes a 5° seat angle. The backrest center line, set at 10° from the vertical, made a seat-to-backrest angle of 95°, which is also a comfort angle. The center of lumbar support is shown as 11" (279 mm) to the seat reference plane, which is 0.5" (13 mm) less for compactness. This leaves a 3" (76 mm) clear opening for the buttock, and 5" (127 mm) for sacrum support 3" (76mm) above and below the center of lumbar support. The remaining distance at the top is for thoracic support, making the backrest 20" (500 mm) high.

Now this same analysis is shown for the small 1 percentile woman. The chosen height of the center of the lumbar pressure became 8" (203 mm), with 2" (51 mm) above and below the center of lumbar pressure.

Analyzing the seat variations, we find the seat requires a vertical adjustment of 4.4" (112 mm) and a horizontal adjustment of 7" (178 mm), which seemed reasonable.

The steering wheel is plotted in the optimum position for both drivers. It should telescope 5" (127 mm) and angle from 30 to 60°.

The most useful hand positions are drawn in for both operators. Their 5 percentile forces are listed; from this we learn to use only the 5 percentile values of the 1 percentile woman.

Vision lines and color-perception limitations are indicated for the vertical head positions. The head can tilt forward 15° with comfort. In fact, the head can tilt easily 30° forward and backward. The maximum rotation is about 50° forward and backward.

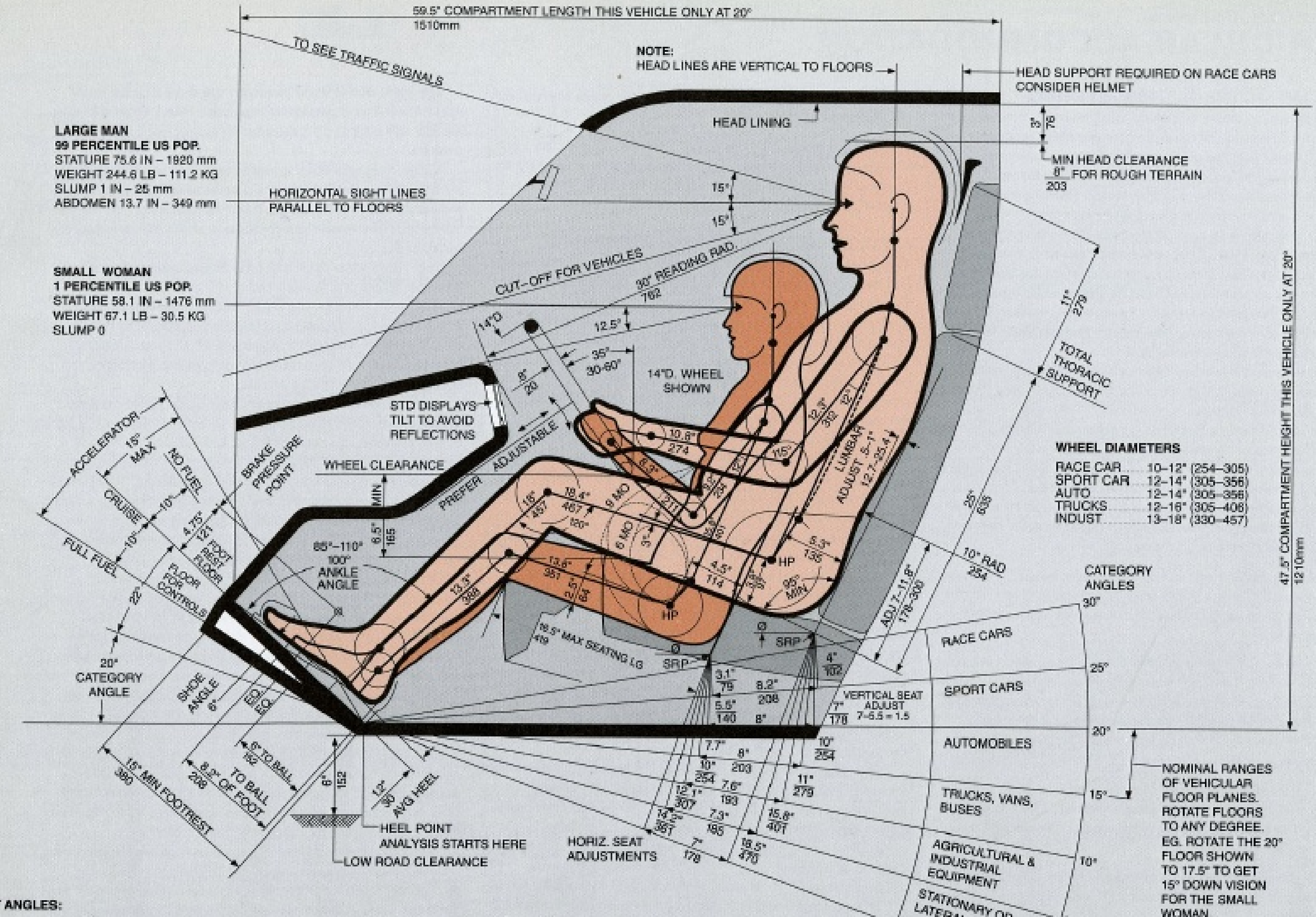
Top views were drawn to help locate control areas for both the 99 percentile man and the 1 percentile woman. Starting with the legs and fixing both within the comfort range yielded a common accelerator position. The brake and clutch were easy to locate, leaving a 2" (51 mm) minimum between each foot control to prevent an inadvertent operation of the wrong control.

A major concern was the analysis of the hand console areas. The best location appeared to be 4" (102 mm) in back of the heel line and running back 12" (305 mm). This important console is located 11" (280 mm) from the operator's center line, and it extends outward 5" (127 mm). It is easy to reach. Beyond it is a dotted line showing a larger console area; any area outside the primary console should have only secondary controls. This entire console must be at least 2" (51 mm) below the armrests.

The armrest spacing of 20.5" (520 mm) is a fair compromise distance; 22" (559 mm) is optimum for drivers wearing very heavy clothing. The armrest width size of 3" (76 mm) is comfortable; avoid the 2" (51 mm) minimum. An armrest length of 8" (203 mm) is short, to avoid overlapping the primary console to such an extent that the small woman would encounter trouble making some adjustments.

If we were to design for the 5 percentile woman, who is 59.8" (1520 mm) tall, the up-and-down seat adjustment would be 4" (102 mm), and the forward-and-aft adjustment would be 5" (127 mm). This condition might be more acceptable, and the armrests could be 10" (254 mm) long. Smaller women may use the 5 percentile seat by using a 120° knee angle and tilting the pelvic bone forward.

Vision angles and head-tilt angles are shown in the side views. Color-detection angles are shown adjacent to the horizontal sightline. Reaches and ranges are given; note that the bent trunk dimension may be limited by shoulder safety belts.



COMFORT ANGLES:

SEAT ANGLES...95°–100° FOR ALERT
KNEE ANGLE 110°–120° FOR STRENGTH
ANKLE ANGLE...90°–100° FOR COMFORT
ELBOW ANGLE...80°–165° FOR COMFORT
UPPER ARM ANGLE.....0°– 35° FOR COMFORT

NOTE:
SHANK AND THIGH LINKS ARE FORESHORTENED FOR 15° LEG SPREAD IN PLAN

NOTE:
SEAT REFERENCE PLANE ANGLES Ø ARE EQUAL TO CATEGORY ANGLES. COMPARTMENTS CHANGE

Vision angles are given for the left eye only; the same angles apply for the right eye. All colors can be seen 30° on either side of the head, looking straight ahead, but not all colors by the same eye. Binocular and monocular fields of view are indicated; these, of course, rotate with the head. Easy and maximum head movements are illustrated.

Special controls and revisions were examined. These drawings were made for a mock-up analysis using wood, plywood, cardboard, plastic, or metal. Scale models do not give the same impression as a full-sized cab, where operators may try out controls and the seating for themselves. On the side view of the 99 percentile man, note the indicated clearances above the head and behind the head for various terrains.

Also note the ball and cylinder grips. Ball grips of 1.5" (38 mm) diameter and cylinder grips of 1.25" (32 mm) diameter are preferable, to satisfy the smallest users.

FORCES FOR HAND AND FOOT CONTROLS

On the chart entitled "Strength of Men and Women," start with the seated 50 percentile U.S. man. With an optimum knee angle of 110–120°, the ball of his foot reaches the brake pedal with the force of 114 lbf (507 N) for 5 percentile men, 76 lbf (338 N) for 5 percentile women; take 2/3 x 76 = 50 lbf (222 N) for a no-strain reach. The brake pedal is nearly straight forward and is good for all users.

Regarding the accelerator, see the chart "Foot Measurements and Pedal Design." The resting foot is shown in a posture that is good for a cruise speed; an angle of 10° below this would be for a high speed, and 10° above would be for 0°. An additional 5° above this is the maximum position where the foot rests against the pedal without causing any pedal displacement.

The following summarizes foot control specifications:

Brake

Resistance: 10–50 lbf (44.5–222.4 N)

Free play: 1.2" (30 mm)

Pedal travel (double for boots): 0.5–2.5" (13–64 mm)

Height above accelerator: 1.2" (30 mm) for power-assisted brakes; 3.6" (91 mm) for unassisted foot operation

Accelerator

Resistance: 4–10 lbf (17.8–44.5 N)

Free play: 5°

Maximum travel: 20°

Returning to the chart "Strength of Men and Women," one may determine a few hand forces available. To work at a console on the right-hand side, use the thin line hand and the 5 percentile forces for women.

Since the controls are to the right, take 84% of the values; for example, for pushing 30° forward: 20.2 lbf (90 N), and for pulling: 23.5 lbf (105 N). For pushing very close forward: 19.3 lbf (85.7 N), and for pulling very close forward: 13.4 lbf (59.6 N). These forces are best worked radially to the shoulder pivot.

For moving to the right (still using 84% of the values): 8.4 lbf (37 N); and for moving to the left: 12.6 lbf (57.1 N). In the back position, for moving to the right: 9.2 lbf (41.2 N); and for moving to the left: 10.9 lbf (48.7 N).

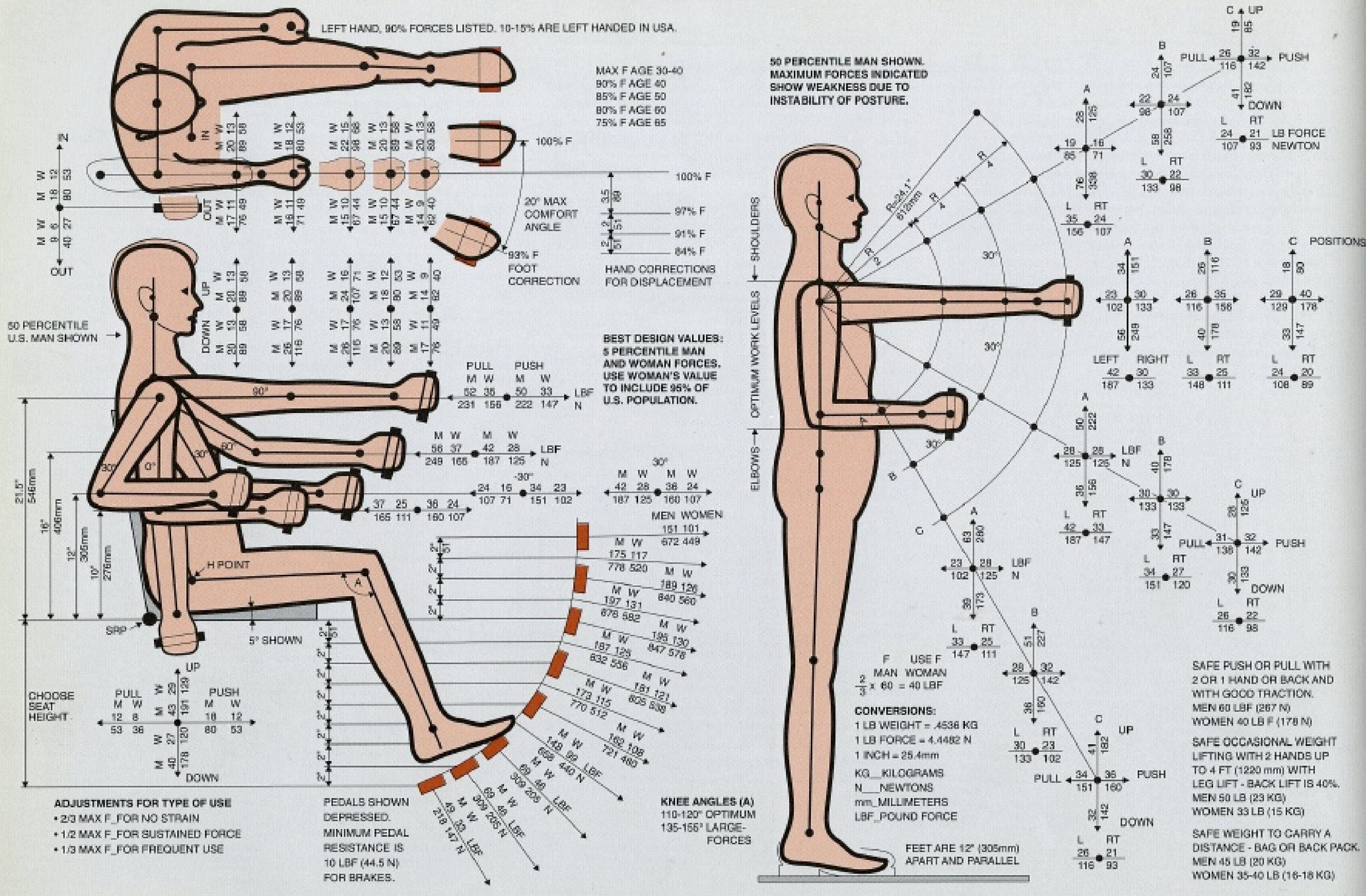
Other values may be taken to suit a particular condition.

Looking at the man on the right, we find that his body posture is not stable. Any forces may be chosen, but take 2/3 of the values shown for the small woman in order to include 99% of the adult population.

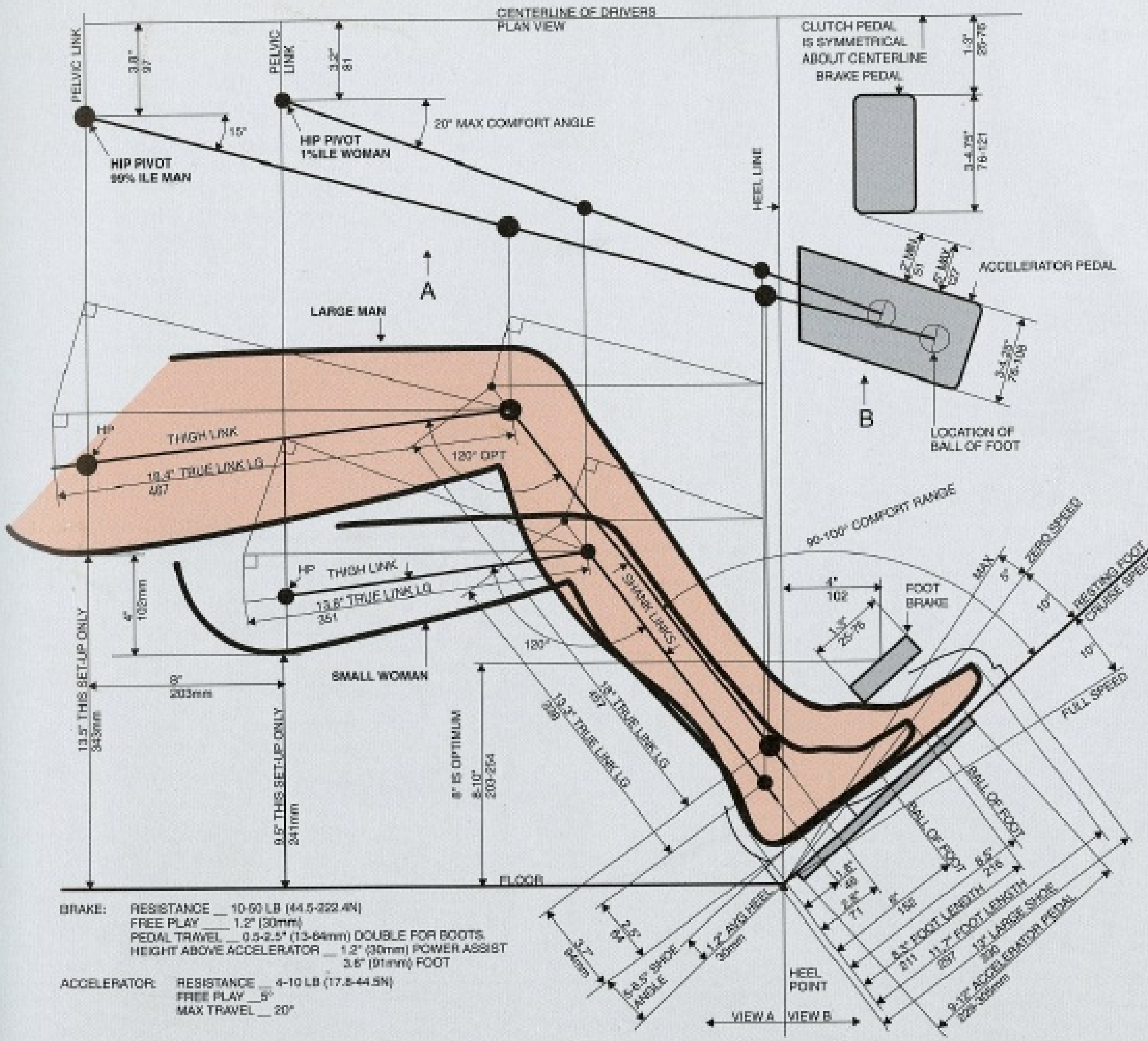
Grip Strength

	Maximum kg	Duration in sec
Men	59.3	63.1
Women	35.5	73.9

In general, muscle strength is greater in men than in women, while physical endurance tends to be greater in women than in men.

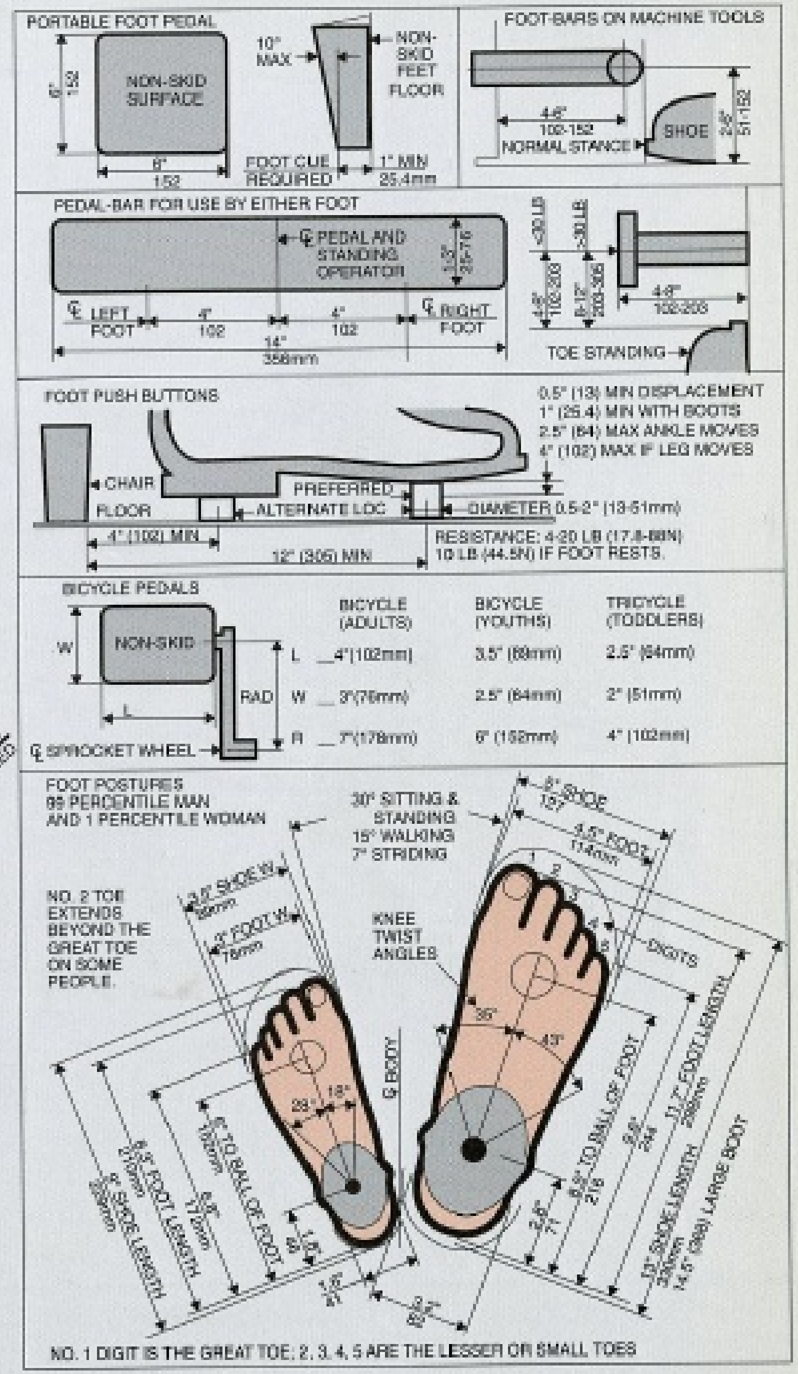

LEFT HAND, 90% FORCES LISTED. 10-15% ARE LEFT HANDED IN USA.
MAX F AGE 30-40
90% F AGE 40
85% F AGE 50
80% F AGE 60
75% F AGE 65
100% F
100% F
20° MAX COMFORT ANGLE
97% F
91% F
84% F
93% F FOOT CORRECTION
HAND CORRECTIONS FOR DISPLACEMENT
50 PERCENTILE U.S. MAN SHOWN
BEST DESIGN VALUES: 5 PERCENTILE MAN AND WOMAN FORCES. USE WOMAN'S VALUE TO INCLUDE 95% OF U.S. POPULATION.
PULL PUSH
LBF
N
MEN WOMEN
H POINT
SRP
5° SHOWN
CHOOSE SEAT HEIGHT
UP
DOWN
ADJUSTMENTS FOR TYPE OF USE
• 2/3 MAX F_FOR NO STRAIN
• 1/2 MAX F_FOR SUSTAINED FORCE
• 1/3 MAX F_FOR FREQUENT USE
PEDALS SHOWN DEPRESSED. MINIMUM PEDAL RESISTANCE IS 10 LBF (44.5 N) FOR BRAKES.
KNEE ANGLES (A)
110-120° OPTIMUM
135-155° LARGE-FORCES
50 PERCENTILE MAN SHOWN. MAXIMUM FORCES INDICATED SHOW WEAKNESS DUE TO INSTABILITY OF POSTURE.
SHOULDERS
OPTIMUM WORK LEVELS
ELBOWS
R=24.1" 612mm
POSITIONS
LB FORCE
NEWTON
F MAN USE F WOMAN
2/3 x 60 = 40 LBF
CONVERSIONS:
1 LB WEIGHT = .4536 KG
1 LB FORCE = 4.4482 N
1 INCH = 25.4mm
KG__KILOGRAMS
N___NEWTONS
mm_MILLIMETERS
LBF_POUND FORCE
FEET ARE 12" (305mm) APART AND PARALLEL
SAFE PUSH OR PULL WITH 2 OR 1 HAND OR BACK AND WITH GOOD TRACTION.
MEN 60 LBF (267 N)
WOMEN 40 LB F (178 N)
SAFE OCCASIONAL WEIGHT LIFTING WITH 2 HANDS UP TO 4 FT (1220 mm) WITH LEG LIFT - BACK LIFT IS 40%.
MEN 50 LB (23 KG)
WOMEN 33 LB (15 KG)
SAFE WEIGHT TO CARRY A DISTANCE - BAG OR BACK PACK.
MEN 45 LB (20 KG)
WOMEN 35-40 LB (16-18 KG)

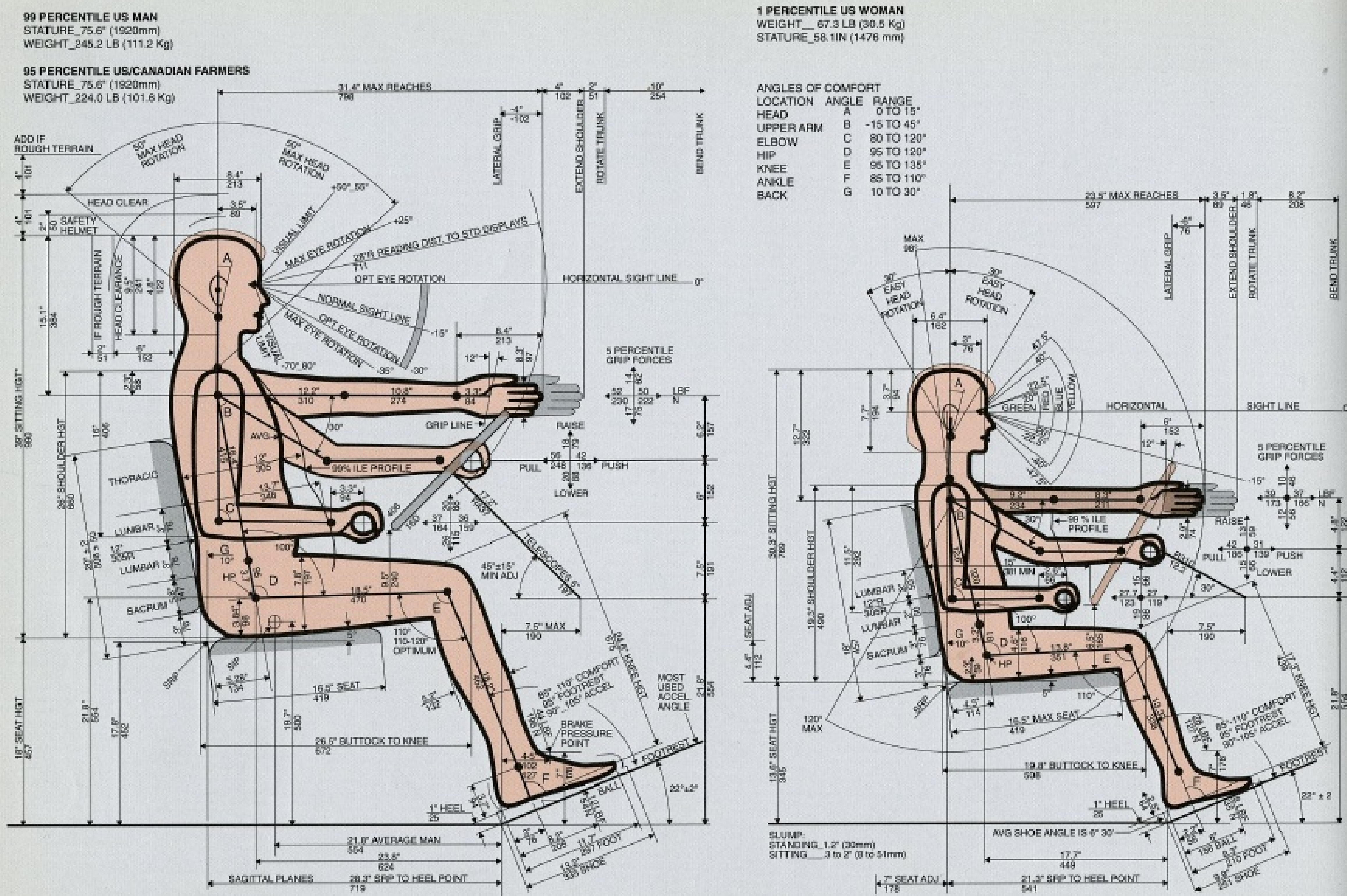
FOOT CONTROLS ON VEHICLES

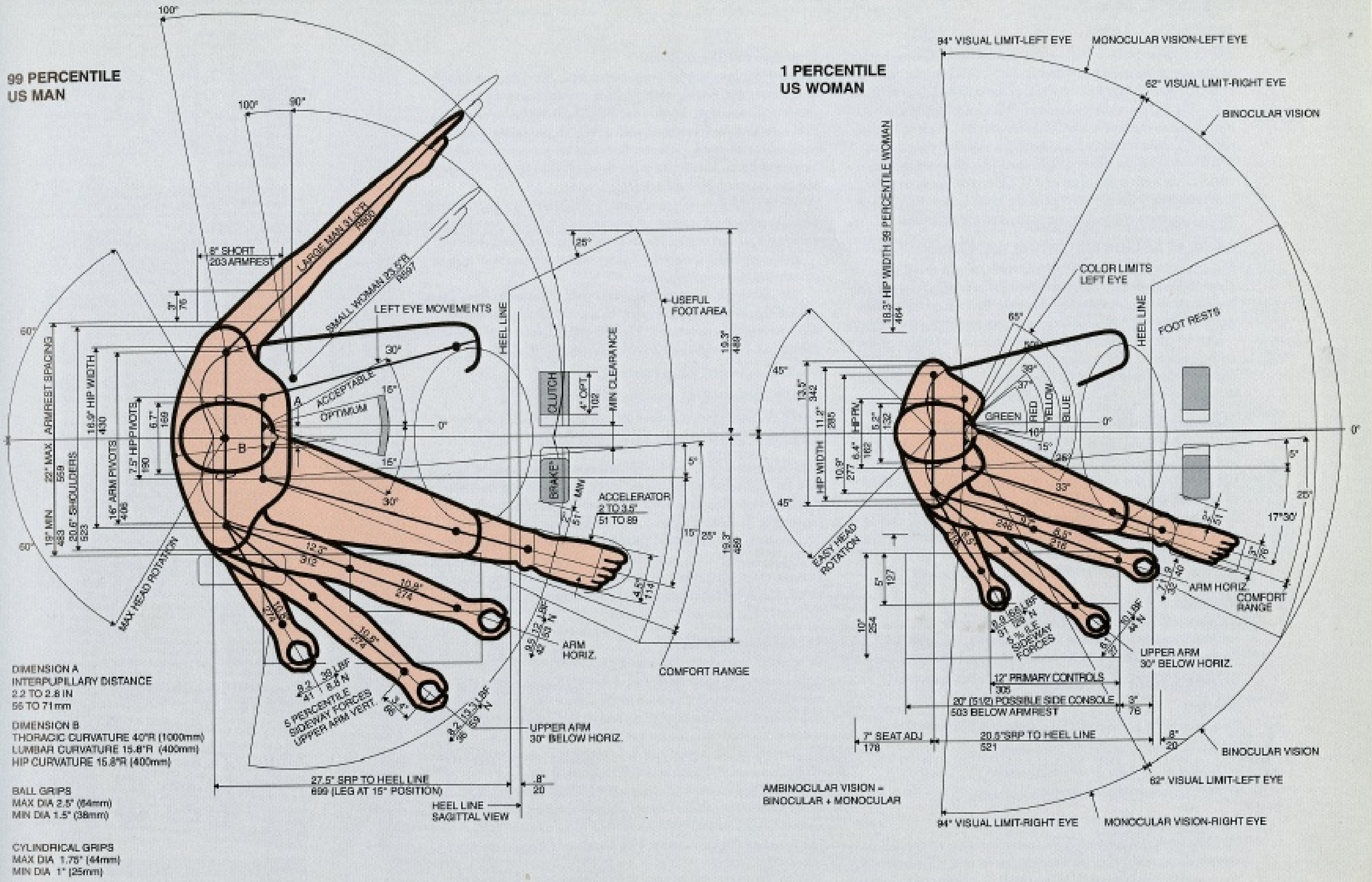


BRAKE: RESISTANCE __ 10-50 LB (44.5-222.4N)
FREE PLAY ____ 1.2" (30mm)
PEDAL TRAVEL __ 0.5-2.5" (13-64mm) DOUBLE FOR BOOTS
HEIGHT ABOVE ACCELERATOR __ 1.2" (30mm) POWER ASSIST
3.6" (91mm) FOOT

ACCELERATOR: RESISTANCE __ 4-10 LB (17.8-44.5N)
FREE PLAY __ 5°
MAX TRAVEL __ 20°




99 PERCENTILE US MAN
STATURE_75.6" (1920mm)
WEIGHT_245.2 LB (111.2 Kg)
95 PERCENTILE US/CANADIAN FARMERS
STATURE_75.6" (1920mm)
WEIGHT_224.0 LB (101.6 Kg)
1 PERCENTILE US WOMAN
WEIGHT__67.3 LB (30.5 Kg)
STATURE_58.1IN (1476 mm)
ANGLES OF COMFORT
LOCATION ANGLE RANGE
HEAD A 0 TO 15°
UPPER ARM B -15 TO 45°
ELBOW C 80 TO 120°
HIP D 95 TO 120°
KNEE E 95 TO 135°
ANKLE F 85 TO 110°
BACK G 10 TO 30°
31.4" MAX REACHES 798
ADD IF ROUGH TERRAIN
50° MAX HEAD ROTATION
HEAD CLEAR
SAFETY HELMET
VISUAL LIMIT
MAX EYE ROTATION
28"R READING DIST TO STD DISPLAYS 711
OPT EYE ROTATION
HORIZONTAL SIGHT LINE
NORMAL SIGHT LINE
LATERAL GRIP
EXTEND SHOULDER
ROTATE TRUNK
BEND TRUNK
5 PERCENTILE GRIP FORCES
GRIP LINE
RAISE
PULL
PUSH
LOWER
99% ILE PROFILE
THORACIC
LUMBAR
SACRUM
TELESCOPES 6"
45°±15° MIN ADJ
7.5" MAX 190
110° 110-120° OPTIMUM
16.5" SEAT 419
26.5" BUTTOCK TO KNEE 672
MOST USED ACCEL ANGLE
85°-110° COMFORT 95° FOOTREST 90°-105° ACCEL
BRAKE PRESSURE POINT
FOOTREST
1" HEEL 25
BALL
21.8" AVERAGE MAN 554
23.8" 624
SAGITTAL PLANES
28.3" SRP TO HEEL POINT 719
13.2" 335 SHOE
11.7" 297 FOOT
38" SITTING HGT 965
28" SHOULDER HGT 660
18" SEAT HGT 457
23.5" MAX REACHES 597
EASY HEAD ROTATION
GREEN
RED
BLUE
YELLOW
HORIZONTAL SIGHT LINE
30.3" SITTING HGT 769
19.3" SHOULDER HGT 490
13.6" SEAT HGT 345
SEAT ADJ
16.5" MAX SEAT 419
19.8" BUTTOCK TO KNEE 503
AVG SHOE ANGLE IS 6° 30'
17.7" 449
21.3" SRP TO HEEL POINT 541
7" SEAT ADJ 178
SLUMP:
STANDING_1.2" (30mm)
SITTING__3 to 2" (8 to 51mm)
9.9" 251 SHOE
8.3" 210 FOOT
22° ± 2


99 PERCENTILE
US MAN
1 PERCENTILE
US WOMAN
100°
90°
8" SHORT
203 ARMREST
LARGE MAN 31.5"R
SMALL WOMAN 23.5"R
LEFT EYE MOVEMENTS
HEEL LINE
ACCEPTABLE
OPTIMUM
30°
15°
0°
CLUTCH
BRAKE
4" OPT
102
MIN CLEARANCE
USEFUL
FOOT AREA
19.3"
489
25°
5°
15°
ACCELERATOR
2 TO 3.5"
51 TO 89
ARMREST SPACING
22" MAX
559
18.9" HIP WIDTH
430
16" ARM PIVOTS
406
7.5" HIP PIVOTS
190
6.7"
169
20.6" SHOULDERS
523
19" MIN
483
60°
MAX HEAD ROTATION
12.3"
312
10.8"
274
ARM
HORIZ.
5 PERCENTILE
SIDEWAY FORCES
UPPER ARM VERT.
UPPER ARM
30° BELOW HORIZ.
COMFORT RANGE
DIMENSION A
INTERPUPILLARY DISTANCE
2.2 TO 2.8 IN
56 TO 71mm
DIMENSION B
THORACIC CURVATURE 40"R (1000mm)
LUMBAR CURVATURE 15.8"R (400mm)
HIP CURVATURE 15.8"R (400mm)
BALL GRIPS
MAX DIA 2.5" (64mm)
MIN DIA 1.5" (38mm)
CYLINDRICAL GRIPS
MAX DIA 1.75" (44mm)
MIN DIA 1" (25mm)
27.5" SRP TO HEEL LINE
699 (LEG AT 15° POSITION)
.8"
20
HEEL LINE
SAGITTAL VIEW
94° VISUAL LIMIT-LEFT EYE
MONOCULAR VISION-LEFT EYE
62° VISUAL LIMIT-RIGHT EYE
BINOCULAR VISION
18.3" HIP WIDTH 99 PERCENTILE WOMAN
464
COLOR LIMITS
LEFT EYE
HEEL LINE
FOOT RESTS
GREEN
RED
YELLOW
BLUE
45°
13.5"
342
11.2"
285
HIP PIV.
5.2"
132
HIP WIDTH
10.9"
277
6.4"
162
EASY HEAD
ROTATION
17°30'
ARM HORIZ.
COMFORT
RANGE
UPPER ARM
30° BELOW HORIZ.
5"
127
10"
254
12" PRIMARY CONTROLS
305
20" (51/2) POSSIBLE SIDE CONSOLE
503 BELOW ARMREST
3"
76
7" SEAT ADJ
178
20.5"SRP TO HEEL LINE
521
.8"
20
AMBINOCULAR VISION =
BINOCULAR + MONOCULAR
62° VISUAL LIMIT-LEFT EYE
94° VISUAL LIMIT-RIGHT EYE
MONOCULAR VISION-RIGHT EYE

DISPLAYS

The preferable reach is that of the small woman sitting, with a radius about the shoulder pivot of 26.5" (67.2 mm) and dropping until it touches the deck of the console. This includes a 3" (76 mm) shoulder movement. With an additional 6" (152 mm) bend to the trunk, she can reach the 24"-wide (610 mm) panel. The best location for a display is in a 30° cone 15° up and down from the relaxed sight line. This allows a perfect visual circle with a diameter of 11" (280 mm) on any of the four consoles. This is the area for the most important displays, with or without manual corrections, and for a monitor.

CIRCULAR ANALOG AND DIGITAL DISPLAYS

Prefer circular dials, semi-circular dials, check dials, and zone-coded dials. Counter, mechanical, and digital dials are useful, as are dot-matrix and segment-matrix readouts and graphic displays. Use simplifying scales and indices as shown.

Avoid ornate pointers. Make the pointer width as required and taper the end of it to match the minor index width. The colors of the pointer and the indices should match, especially if the pointer is to be flush with the indices.

CIRCULAR ANALOG AND GRAPHIC DISPLAYS

Prefer a dial diameter of 2.75–4" (57–102 mm), or for high accuracy, prefer 4–6" (102–152 mm). Start 0 to the left of the bottom of the dial (e.g., at 9 o'clock) and always count clockwise; putting 0 at 12 o'clock is also acceptable. Numbers are usually outside the indices; very small dials, check dials, and zone-coded dials require the numbers inside.

Graphic displays using LEDs and LCDs are easy to read and can convey much information in a small space.

Markings

All numbers should read vertically. Use simple sans-serif numbers and letters. Avoid fancy pointers, trade names, and logos. Keep pointers simple (see drawing). Note the optimum proportions for a clearly recognizable directional arrow.

Pointers

Pointer widths are specified for different dials as follows:

0.031" (.8 mm) for 2" (26 mm) dials.

0.062" (1.6 mm) for 3" (76 mm) dials.

0.094" (2.4 mm) for 4" (101.6 mm) dials.

Pictorial Indicators

Pictures can greatly assist in the interpretation of special relationships (e.g., aircraft altitude, pitch and roll), and also for components (e.g., flap indicators). Symbols must conform directionally with the object or components they represent.

Signal and Warning Lights

Lighted displays can be omnidirectional. They can be simple indicators on a panel, with flashing indicators to signal an abnormal condition. Meters can have signal lights to emphasize that safe limits are being exceeded, and so on. Multi-projection indicators can show pictures, flow charts, numerical readouts, or verbal data. Master warning lights should be used if signals are extensive or beyond normal viewing.

Annunciator panels give visual commands. An annunciator panel displaying a matrix of simple indicators in the optimum viewing area can replace signals on many scattered devices.

Back-lighted panels with color coding are the best way of presenting pictorial displays.

Do not overuse lighted displays, and, if possible, keep them within the 30° cone, preferably in the 15° downward view. Keep colors to a minimum. The following guide to signal light colors has been developed for color-deficient observers:

White is a general status indicator.

Red denotes situation critical; malfunctioning.

Green denotes safe, nominal, or go-ahead conditions.

Amber or Yellow denotes a need for caution.

Consider providing two brightnesses, one for daylight and one for nighttime use. A matte black panel can improve the effectiveness of signals. Isolate the most critical signals from the others. Indicator lights need not be large to be effective; proper choice of color and intensity are the important factors.

Flashing lights are more effective in attracting attention but are more disturbing to the observer. The recommended flash rate is 4 flashes per second, with approximately equal time for light and dark durations.

ELECTRONIC DISPLAYS

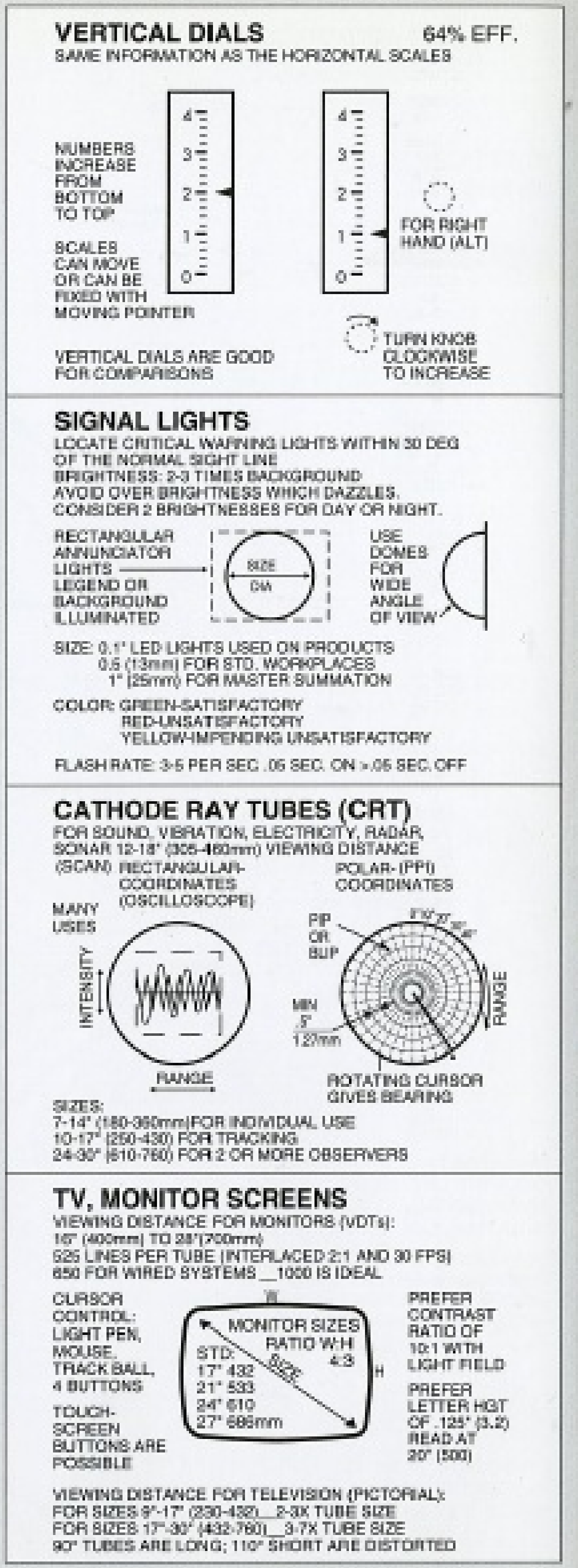
In general, the viewing distance should be 12–18" (305–460 mm). For more individual use, 7–14" (180–360 mm) is a suitable distance. For two or more observers, prefer 24–30" (610–760 mm). The display screen should be perpendicular to the normal sight line, or no greater than 30° off axis.

The minimum signal size is 1 minute of visual angle. The minimum signal duration is 0.2 seconds.

Signal brightness and contrast with the background should be as great as possible. Contrast usually exceeds 1 mL.

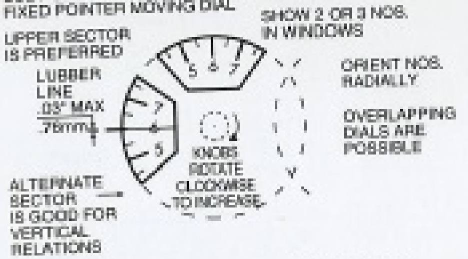
Ambient illumination should not reflect from the face of the panel or display screen. Use hoods or filters, if necessary.

Data in this section are adapted from Humanscale 4/5/6, *1981; Dreyfuss, 1960; and Woodson, 1981.*



OPEN WINDOW DIALS 99% EFF.

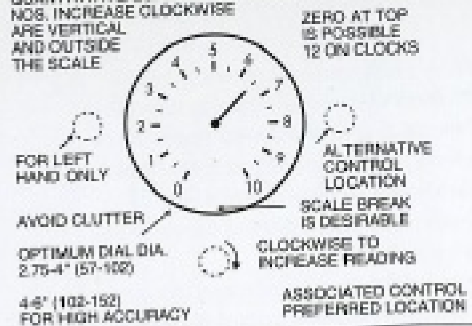
USE FOR QUANTITATIVE DATA ONLY
FIXED POINTER MOVING DIAL



AVOID MANUAL CONTROL AS OPP. TO INCREASE
RULE NOS. INCREASE CLOCKWISE
DIAL ROTATES COUNTERCLOCKWISE TO INCREASE

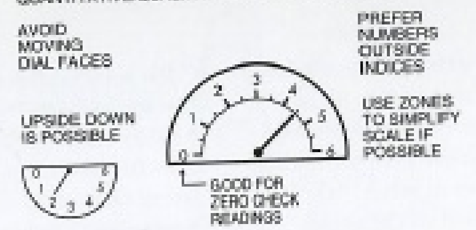
CIRCULAR DIALS 89% EFF.

QUANTITATIVE/QUALITATIVE AND SNAP CHECK



SEMI CIRCULAR DIALS 83% EFF.

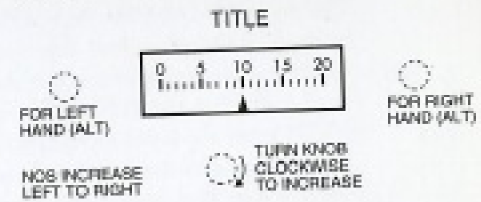
QUANTITATIVE/QUALITATIVE AND SNAP CHECK



AVOID DISTRACTING LOGOS ON ALL DIAL FACES
NOS.AND SPACING OF SCALE MARKINGS ULTIMATELY DETERMINE THE SIZE OF THE DIAL

HORIZONTAL SCALES 72% EFF.

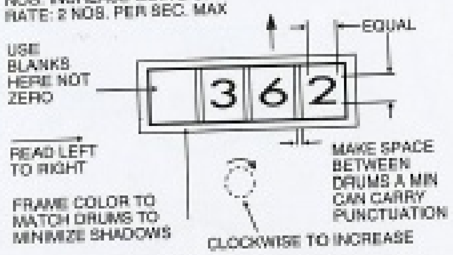
QUANTITATIVE/QUALITATIVE AND SNAP CHECK FOR FIXED SCALES AND MOVING POINTERS
QUANTITATIVE ONLY FOR MOVING SCALES WITH THE POSSIBITY OF USING LONG SCALE TAPES



RECOMMEND FIXED SCALE AND MOVING POINTER

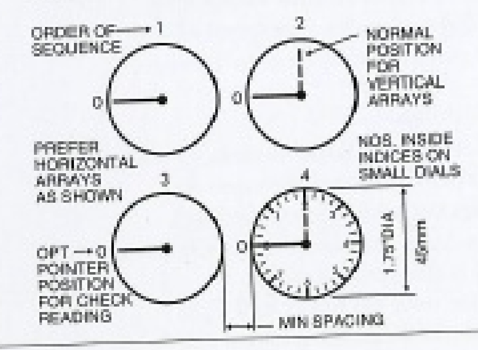
COUNTERS 99% EFF.

FOR QUANTITATIVE READINGS ONLY
NOS. INCREASE GOING UP
RATE: 2 NOS. PER SEC. MAX



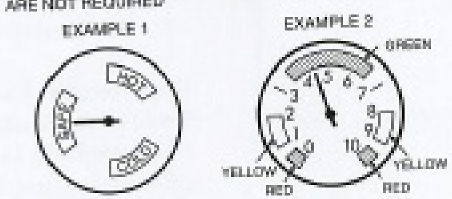
LEAST COUNT NOS. SHOULD SNAP INTO POSITION
ILLUMINATION IS DIFFICULT WITH COUNTERS

CHECK DIALS (FOR GROSS READINGS)



ZONE CODED DIALS

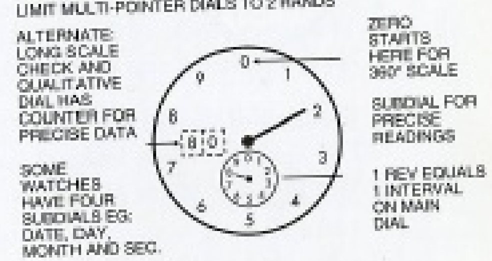
DIAL READING CAN BE SIMPLIFIED BY THE USE OF ZONE MARKINGS IF PRECISE NUMERICAL VALUES ARE NOT REQUIRED



CONSIDER COLOR CODING THE ZONE MARKINGS
GREEN-SAFE, NORMAL, SATISFACTORY, DESIRABLE
YELLOW-CAUTION, WARNING
RED-DANGER, UNDESIRABLE, INEFFICIENT

MULTI-REVOLUTION DIALS

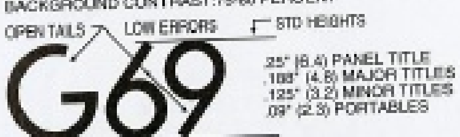
LIMIT MULTI-POINTER DIALS TO 2 HANDS



MULTI-POINTER DIALS ARE CONFUSING TO READ
THE COMMON ALARM CLOCK WORKS IF SWEEP HAND IS RED AND ALARM HAND IS INCONSPICUOUS

CHARACTERS

ALL CHARACTERS TO READ VERTICALLY
NO VERTICAL WORDS
PREFER SANS SERIF (FUTURA MED. OR OTHER)
STROKE/HEIGHT 1:6 BLK ON W. 1:8 W ON BLK
BACKGROUND CONTRAST:75-80 PERCENT



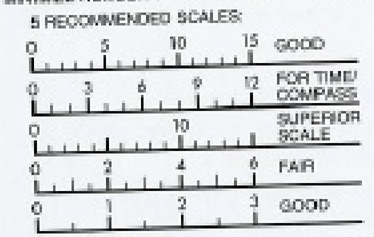
HEIGHT FOR 28" (710mm)VIEWING DISTANCE:
USE LARGER VALUES FOR VISUALLY IMPAIRED

CRITICAL (MOVING SCALES) — .2-.3" (5-8mm)
CRITICAL (STATIONARY) — .16-.3" (4-8mm)
NONCRITICAL (INSTRUCTIONS) — .05-.2" (1.3-5mm)

OTHER DISTANCES ARE DIRECTLY PROPORTIONAL

SCALES

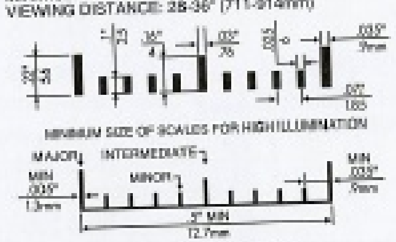
MINIMIZE NUMBER OF MARKINGS IF NOT REQUIRED
5 RECOMMENDED SCALES:



CAN ADD ZEROS OR DECIMALS TO DIGITS ABOVE
AVOID SCALES: 2.5 5 7.5 AND 4 8 12
AVOID VARIABLE SCALES EG LOGARITHMIC
AVOID MIXING DIFFERENT SCALES NEARBY

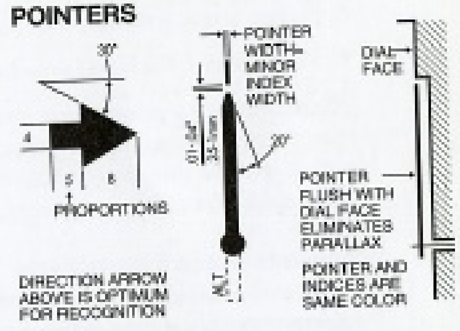
INDICES

MINIMUM SIZE SCALES FOR LOW ILLUMINATION, VIEWING DISTANCE: 28-36" (711-914mm)



MINIMUM SPACE BETWEEN INDICES:
2X INDEX WIDTH IF INDICES ARE WHITE ON BLACK
1X INDEX WIDTH IF INDICES ARE BLACK ON WHITE
SIZES ARE DIRECTLY PROPORTIONAL VIEWING DIST

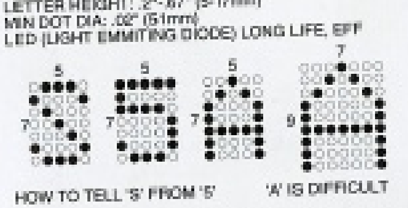
POINTERS



AVOID ORNATE POINTERS WHICH ARE DISTRACTING

DOT-MATRIX READOUT 92% EFF. ILLUMINATED

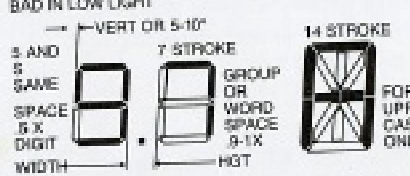
FOR LED, TV, PIN LIGHTS
AVOID LOWER CASE
LETTER HEIGHT: .2"-.67" (5-17mm)
MIN DOT DIA: .02" (.51mm)
LED (LIGHT EMMITING DIODE) LONG LIFE, EFF



5 X 7 DOT MATRIX IS POSSIBLE FOR DIGITS AND CAPS
7 X 9 IS MORE ACCEPTABLE, LOWER CASE IS POOR AND ORIENTAL OR ARABIC IS POSSIBLE
8 X 14 IS USED FOR BOLD CHARACTERS (2 STROKES)

SEGMENT-MATRIX READOUT

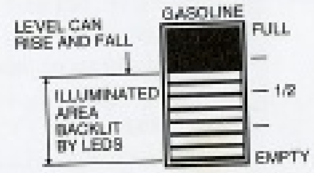
FOR LCD, LED, TV
NOT AS LEGIBLE AS DOT MATRIX DISPLAYS
REFLECTING LIQUID CRYSTAL DISPLAYS (LCD) ARE BAD IN LOW LIGHT



SPACING APPEARS POOR AT TIMES 'A' IS POOR
7 STROKE SEGMENT MOSAIC DISPLAY FORMAT IS ACCEPTABLE FOR DIGITS AND 10 CAPITAL LETTERS
14 STROKES IS USEFUL FOR ALPHANUMERICS
8, 10, 11, 20 AND 54 STROKES DO OCCUR

GRAPHIC DISPLAYS

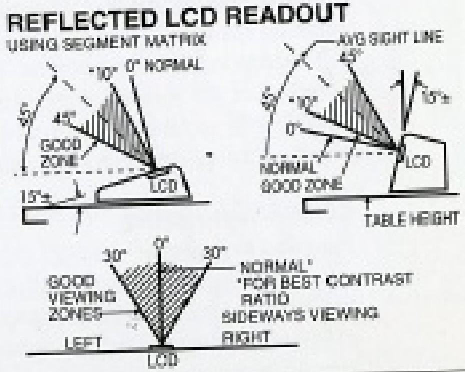
FOR LED, LCD
GOOD FOR QUALITATIVE INFORMATION
GRAPHIC SOLUTIONS ARE POSSIBLE



SYMBOLS CAN BE ILLUMINATED AS WARNINGS
ANIMATED DISPLAY WILL APPEAR IN THE FUTURE AND MAY REPLACE ANALOGS WITH LESS SPACE

REFLECTED LCD READOUT

USING SEGMENT MATRIX



MANUAL CONTROLS

The preferable reach is that of the small woman sitting with a horizontal sight line; her reach amounts to a radius of 26.5" (672 mm) swinging about the shoulder pivot and dropping until it touches the deck of the four consoles. This includes a 3" (75 mm) shoulder movement. For close-in work, take a 12" radius (305 mm) about the elbow pivot of the small woman sitting at one of the consoles. Adding 3" (75 mm) of elbow movement will allow her to touch any area on the deck.

The best height is obtained by starting at the top of her shoulder and running down until her hand touches the deck. The narrow width of the 24" (610 mm) console will permit her to touch any area of the deck.

Economy of Human Motion

Five kinds of motion follow, in order of increasing effort, exertion, and time of operation:

1. Finger.
2. Finger and wrist.
3. Finger, wrist, and forearm.
4. Finger, wrist, forearm, and upper arm.
5. Finger, wrist, forearm, upper arm, and body.

There is one exception: wrist motion can be more fatiguing than finger motion. Try to keep the wrist and forearm in as near a straight line as possible when working with the standard keyboard for monitors.

Accurate Reach Determinants

Graphical analysis of dynamic motions should be made, taking into account the various movements of the shoulder pivot and the different hand postures used with the various controls. Reach can be increased by extending the shoulder, rotating the trunk, and bending the trunk, or by a combination of these motions. The distance varies according to whether the motion takes place directly in front of the operator or to the side (or some point in between) and whether the operator is a woman or a man.

Control Organization

Frequently operated controls should be the most accessible ones, visually as well as physically. Emergency controls may fit this category, but if they involve a risk they must be protected from inadvertent operation. Related controls should be grouped together in a logical pattern.

To achieve rapid, error-free performance, provide ample clearance of 6–8" (152–203 mm) above and around controls in easily reached areas and twice this in harder-to-reach areas to accommodate blind reaching. The sequence of movements during operation of controls should be short, effective, harmonious, and smooth; backtracking, repeated movements, and indirect motions are to be avoided.

Symmetry of motion for simultaneous operations involving both hands saves time and reduces errors. Control motions should be natural, taking muscular efficiency and direction into consideration. Standardization of control location on machines or vehicles reduces errors and accidents when the operator transfers from one piece of equipment to another.

Grip Designs

Hand grips should conform to use and hand motion, and all handles should feel comfortable; use rounded shapes and cylindrical grips. Thin handles cut under heavy loading. Gripping handles that are too large feels insecure. A diameter of 0.875–1.25" (22–32 mm) is the optimal range.

The ball or similar grips are used for heavy and light loading. Their shapes need not be an exact sphere if the handle is locked onto the shaft. For door levers, use the L-shaped, not the T-shaped handle.

High-Torque and Rotary Knobs

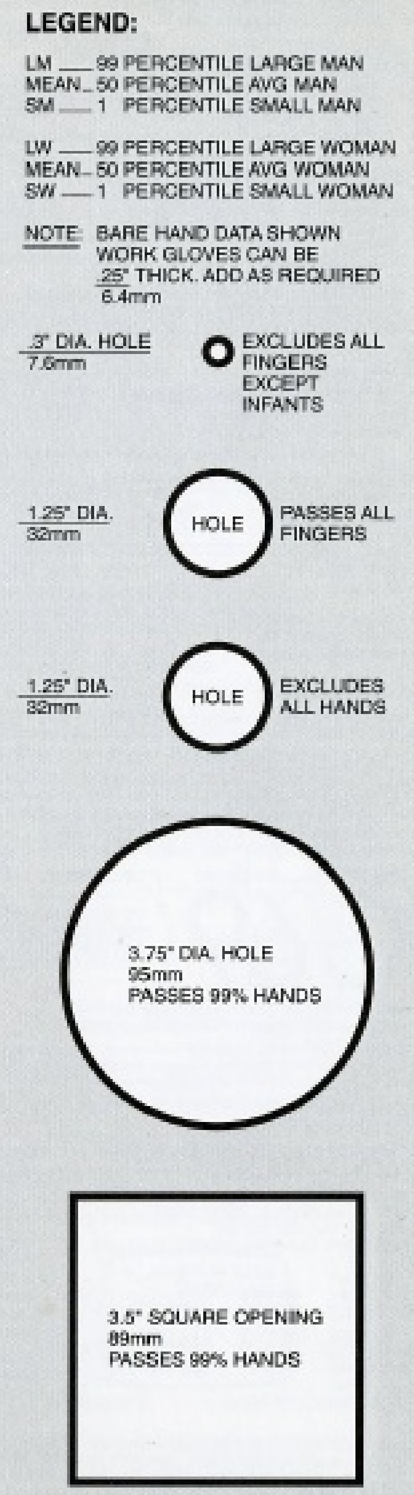
A high-torque knob is a rugged valve knob with a 1.5–3" (38–76 mm) diameter. The periphery is notched for finger grips. Use 1" (25.4 mm) diameter knobs for noncritical adjustments, such as for volume, focus, and dimming, which require little force. Use 2" (51 mm) diameter knobs for critical adjustments, such as tuning or frequency selection. Knurling is advantageous for light finger grips.

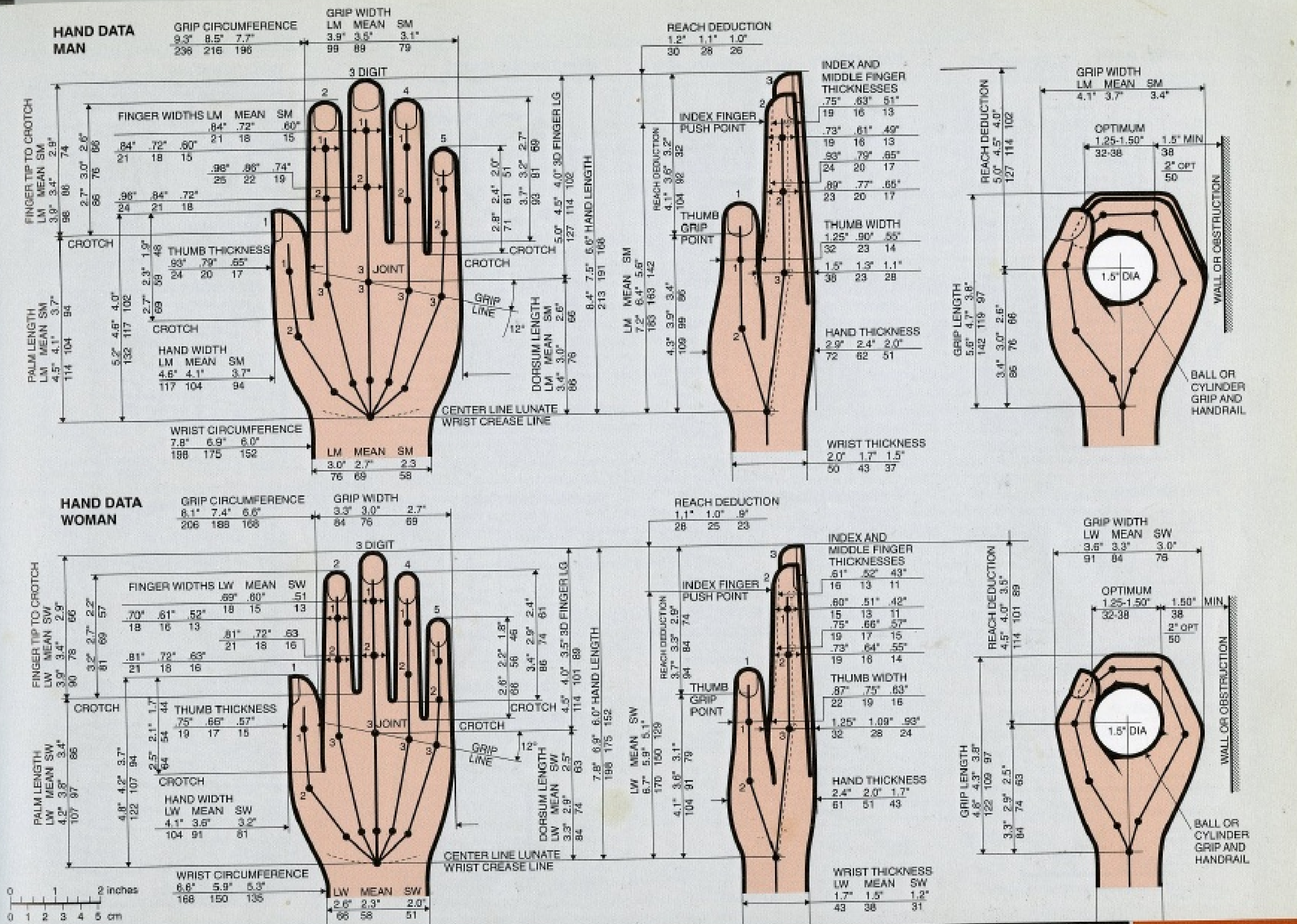
Detented Knobs

Good for multiple positioning, detented knobs are least susceptible to inadvertent operation and provide good space economy. But they are slower than all the above types, requiring precise tactile and visual discrimination. The best diameter is 2" (51 mm) or less with a pointer 0.75" (19 mm) deep.

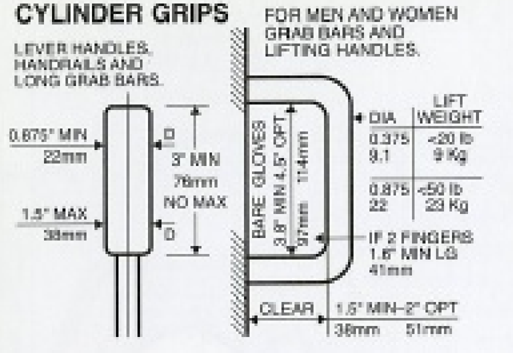
Cranks

Cranks are good for rotations of more than 180°. They are used mostly for machine tools and fine precision work. The smallest of these has a 0.5" (13 mm) radius for model work, and the largest has a 20" (508 mm) radius that can be operated by the average man and the large woman. For all adults, prefer a radius of 8" (203 mm) mounted at the proper height.

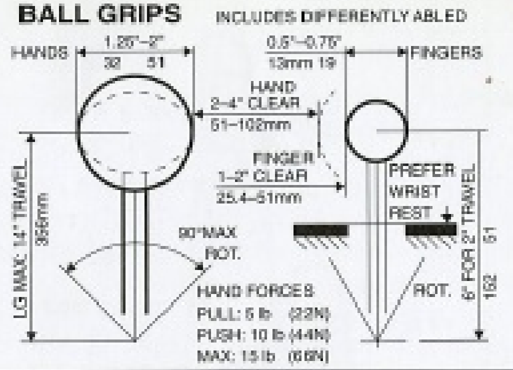



HAND DATA MAN
GRIP CIRCUMFERENCE
9.3" 8.5" 7.7"
236 216 196
GRIP WIDTH
LM MEAN SM
3.9" 3.5" 3.1"
99 89 79
3 DIGIT
FINGER WIDTHS LM MEAN SM
.84" .72" .60"
21 18 15
.84" .72" .60"
21 18 15
.96" .86" .74"
25 22 19
.96" .84" .72"
24 21 18
FINGER TIP TO CROTCH
LM MEAN SM
3.9" 3.4" 2.9"
98 86 74
CROTCH
THUMB THICKNESS
.93" .79" .65"
24 20 17
JOINT
CROTCH
GRIP LINE
12°
PALM LENGTH
LM MEAN SM
4.5" 4.1" 3.7"
114 104 94
HAND WIDTH
LM MEAN SM
4.6" 4.1" 3.7"
117 104 94
WRIST CIRCUMFERENCE
7.8" 6.9" 6.0"
198 175 152
LM MEAN SM
3.0" 2.7" 2.3
76 69 58
CENTER LINE LUNATE
WRIST CREASE LINE
DORSUM LENGTH
LM MEAN SM
3.4" 3.0" 2.6"
86 76 66
3D FINGER LG
HAND LENGTH
LM MEAN SM
8.4" 7.5" 6.6"
213 191 168
REACH DEDUCTION
1.2" 1.1" 1.0"
30 28 26
INDEX AND MIDDLE FINGER THICKNESSES
.75" .63" .51"
19 16 13
.73" .61" .49"
19 16 13
.93" .79" .65"
24 20 17
.89" .77" .65"
23 20 17
INDEX FINGER PUSH POINT
THUMB GRIP POINT
THUMB WIDTH
1.25" .90" .55"
32 23 14
1.5" 1.3" 1.1"
38 23 28
HAND THICKNESS
2.9" 2.4" 2.0"
72 62 51
WRIST THICKNESS
2.0" 1.7" 1.5"
50 43 37
GRIP WIDTH
LM MEAN SM
4.1" 3.7" 3.4"
OPTIMUM
1.25-1.50"
32-38
1.5" MIN
38
2" OPT
50
1.5" DIA
WALL OR OBSTRUCTION
REACH DEDUCTION
5.0" 4.5" 4.0"
127 114 102
GRIP LENGTH
5.6" 4.7" 3.8"
142 119 97
BALL OR CYLINDER GRIP AND HANDRAIL
HAND DATA WOMAN
GRIP CIRCUMFERENCE
8.1" 7.4" 6.6"
206 188 168
GRIP WIDTH
3.3" 3.0" 2.7"
84 76 69
3 DIGIT
FINGER WIDTHS LW MEAN SW
.69" .60" .51
18 15 13
.70" .61" .52"
18 16 13
.81" .72" .63
21 18 16
.81" .72" .63"
21 18 16
FINGER TIP TO CROTCH
LW MEAN SW
3.9" 3.4" 2.9"
CROTCH
THUMB THICKNESS
.75" .66" .57"
19 17 15
JOINT
CROTCH
GRIP LINE
12°
CROTCH
PALM LENGTH
LW MEAN SW
4.2" 3.8" 3.4"
107 97 86
HAND WIDTH
LW MEAN SW
4.1" 3.6" 3.2"
104 91 81
WRIST CIRCUMFERENCE
6.6" 5.9" 5.3"
168 150 135
LW MEAN SW
2.6" 2.3" 2.0"
66 58 51
CENTER LINE LUNATE
WRIST CREASE LINE
DORSUM LENGTH
LW MEAN SW
3.3" 2.9" 2.5"
84 74 63
3D FINGER LG
HAND LENGTH
7.8" 6.9" 6.0"
198 175 152
REACH DEDUCTION
1.1" 1.0" .9"
28 25 23
INDEX AND MIDDLE FINGER THICKNESSES
.61" .52" .43"
16 13 11
.60" .51" .42"
15 13 11
.75" .66" .57"
19 17 15
.73" .64" .55"
19 16 14
INDEX FINGER PUSH POINT
THUMB GRIP POINT
THUMB WIDTH
.87" .75" .63"
22 19 16
1.25" 1.09" .93"
32 28 24
HAND THICKNESS
2.4" 2.0" 1.7"
61 51 43
WRIST THICKNESS
LW MEAN SW
1.7" 1.5" 1.2"
43 38 31
GRIP WIDTH
LW MEAN SW
3.6" 3.3" 3.0"
91 84 76
OPTIMUM
1.25-1.50"
32-38
1.50" MIN
38
2" OPT
50
1.5" DIA
WALL OR OBSTRUCTION
REACH DEDUCTION
4.5" 4.0" 3.5"
114 101 89
GRIP LENGTH
4.8" 4.3" 3.8"
122 109 97
BALL OR CYLINDER GRIP AND HANDRAIL
0 1 2 inches
0 1 2 3 4 5 cm

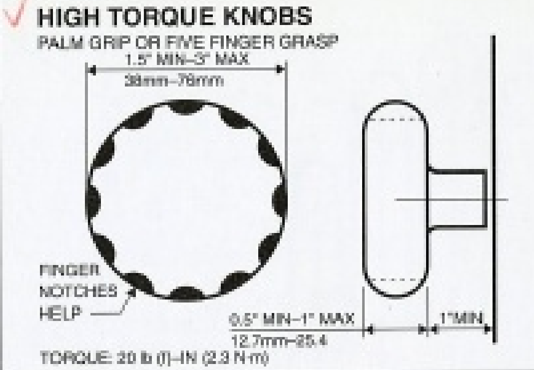
CYLINDER GRIPS



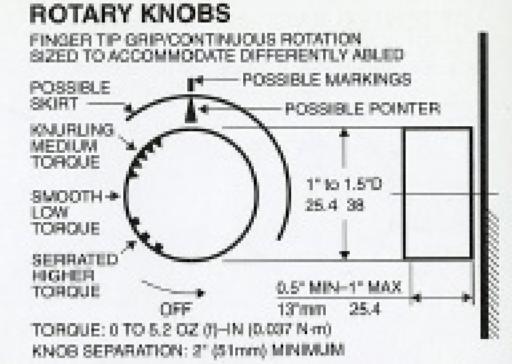
BALL GRIPS



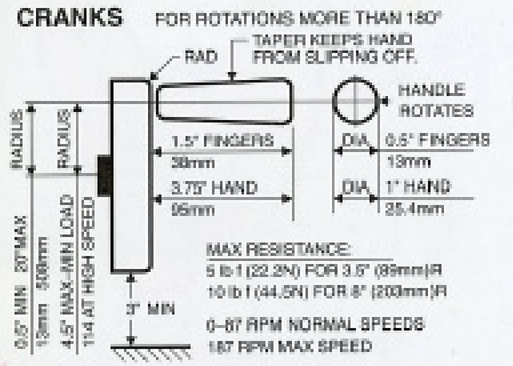
HIGH TORQUE KNOBS



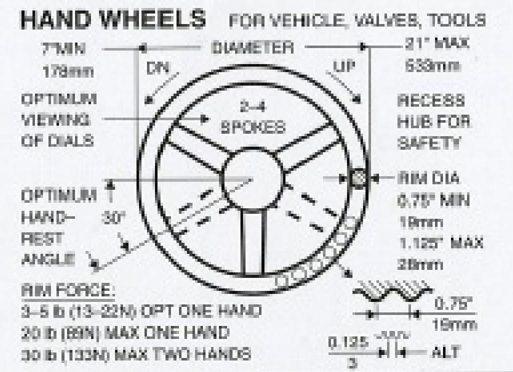
ROTARY KNOBS



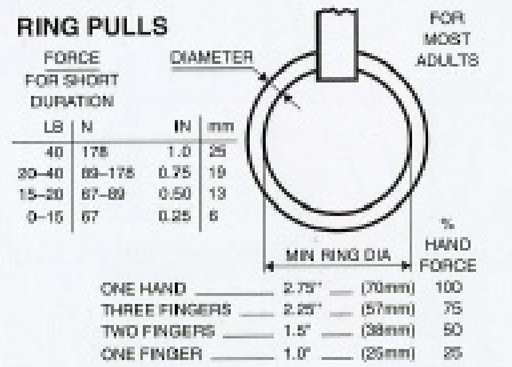
CRANKS



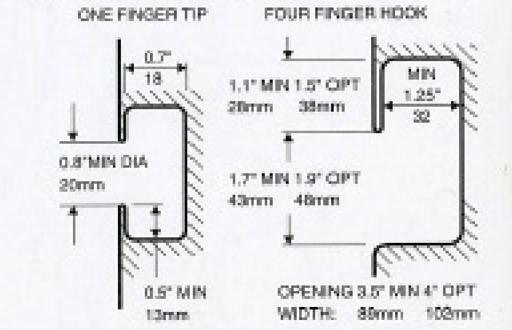
HAND WHEELS



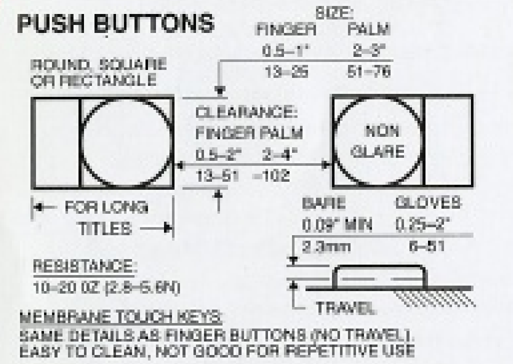
RING PULLS



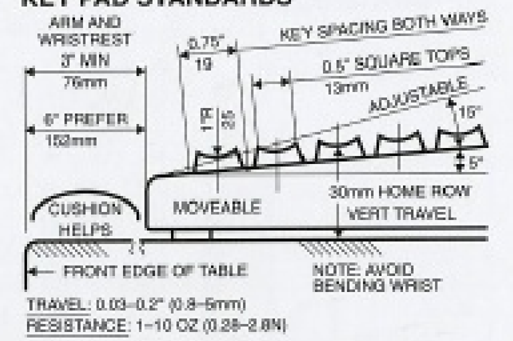
FLUSH FINGER PULLS



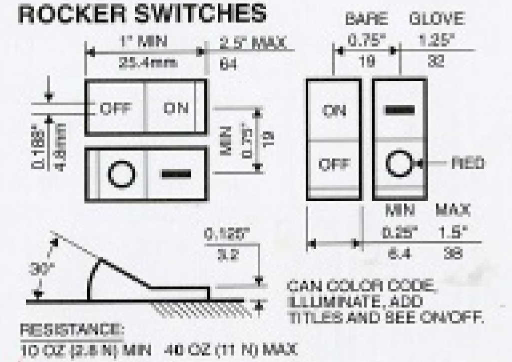
PUSH BUTTONS



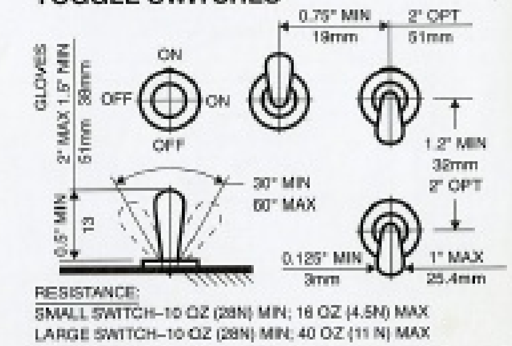
KEY PAD STANDARDS



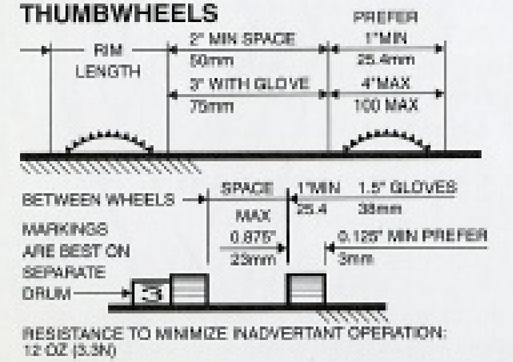
ROCKER SWITCHES



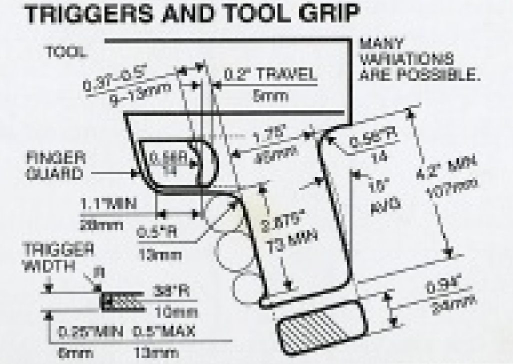
TOGGLE SWITCHES



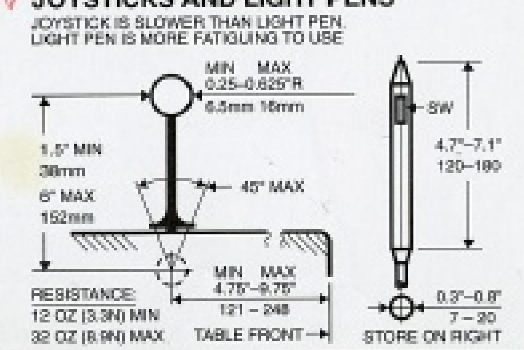
THUMBWHEELS



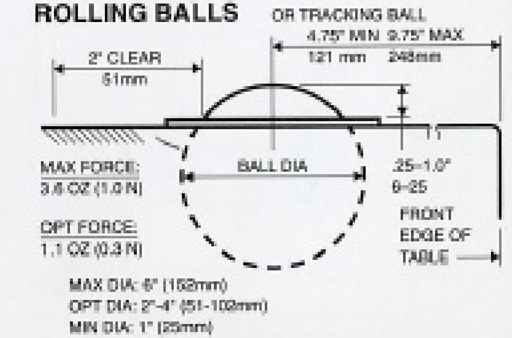
TRIGGERS AND TOOL GRIP

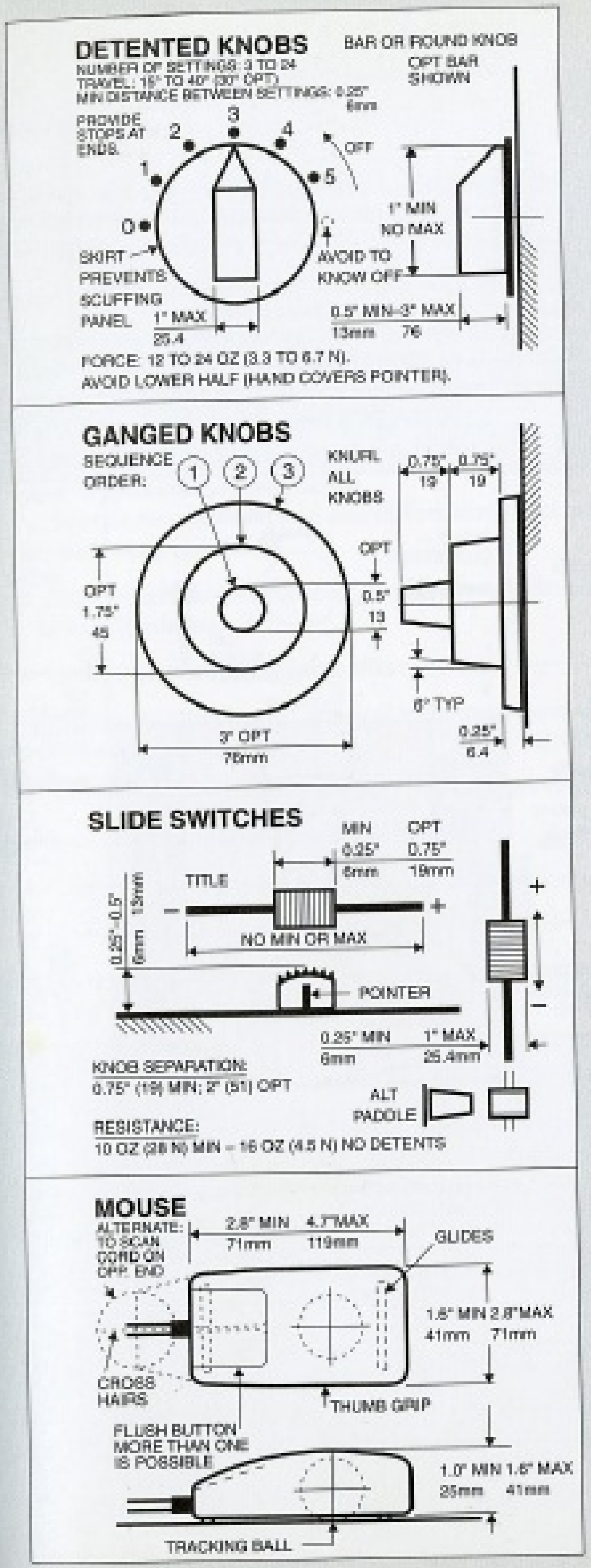


JOYSTICKS AND LIGHT PENS



ROLLING BALLS





Hand Wheels

Hand wheels are good for automobiles, airplanes, tools, and valves. Finger grips should be provided where heavy loads are involved. For vehicles, prefer wheels of 7–21" (178–533 mm), with three spokes providing an open view of displays or traffic.

Push Buttons

Push buttons are available in a great variety of types. Sizes run 0.5–1" (13–25 mm) in height and 0.5–2" (13–51 mm) in length; long labels can be put on the faces of the longer buttons. Palm sizes are also given.

Buttons should give the operator positive feedback to show activation of the control. This can be provided by incorporating a sensory or audible click when the motion is carried out. Push-on-push-off types are not as good, because they cancel out the expected movements for "on."

Rocker, Toggle, and Slide Switches

Rocker switches carry important messages on the front face, in addition to the titles that must appear on the panel face. Rocker switches must be oriented the same way as the toggle switch: "off" is always down or to the left. The simplest toggle switches are accurate if they follow this rule. If triple-position switches are used, their position may not be immediately apparent. Toggles today take many forms; some have a flip cover, and so on. Slide switches must have the "off" down or to the left. Their position is difficult to determine if the slot is long.

Thumbwheels

Thumbwheels, which are difficult to read, must also be "off" when down or to the left. They are convenient and widely used on small audio receivers and players.

Triggers and Tool Grips

Provide a full finger grip for the trigger of at least 1.1" (27 mm) in diameter for use with gloves. Other dimensions of the hand grip can vary depending on the force to be exerted as long as the minimums are preserved.

Joysticks and Light Pens

Joysticks take longer to use than a light pen, while the light pen is more fatiguing to use, because it needs to be precisely fixed upon its object.

Diameter ranges are as follows:

Maximum diameter: 6" (152 mm). Offset is 1" (25.4 mm).

Optimum diameter: 3–4" (76–102 mm). Offset is 0.8" (20.3 mm).

Minimum diameter: 1.25" (32 mm). Offset is 0.4" (10 mm).

Computer Mice

The mouse range is ample as taken from military sources.

Length: 2.8–4.7" (71–119 mm).

Width: 1.6–2.8" (41–7 mm).

Depth: 1.0–1.6" (25–41 mm).

The smallest unit is best. As an alternative, there is a scanning device. In this case, the cord removes to the back end or to the operator's side.

Foot Movement and Pedal Design

Consult "Vehicular Accommodation" and refer to the left side of the drawing for pedal design. The brake pedal width is 3" (76 mm x 4.75" (121 mm)); this is optimal for industrial purposes.

The accelerator must not be outside the comfort angle of any operator. In this case, 20° is the maximum angle for the small woman. The comfort range is based on the accommodation of both the foot of the large man and of the small woman, so that each can place the ball of the foot on the pedal. The maximum angle is 30° from the vertical line. A speed of zero is at 35°, the resting foot position is at 45°, and full speed is at 55°. The latter is the floor plane; however, the floor plane on the left side is 45° for the resting foot.

In the same drawing, the foot positions are listed at the bottom right, showing the 99 percentile man and the 1 percentile woman. The drawing shows the standing or sitting positions and gives ball-of-the-foot locations for both.

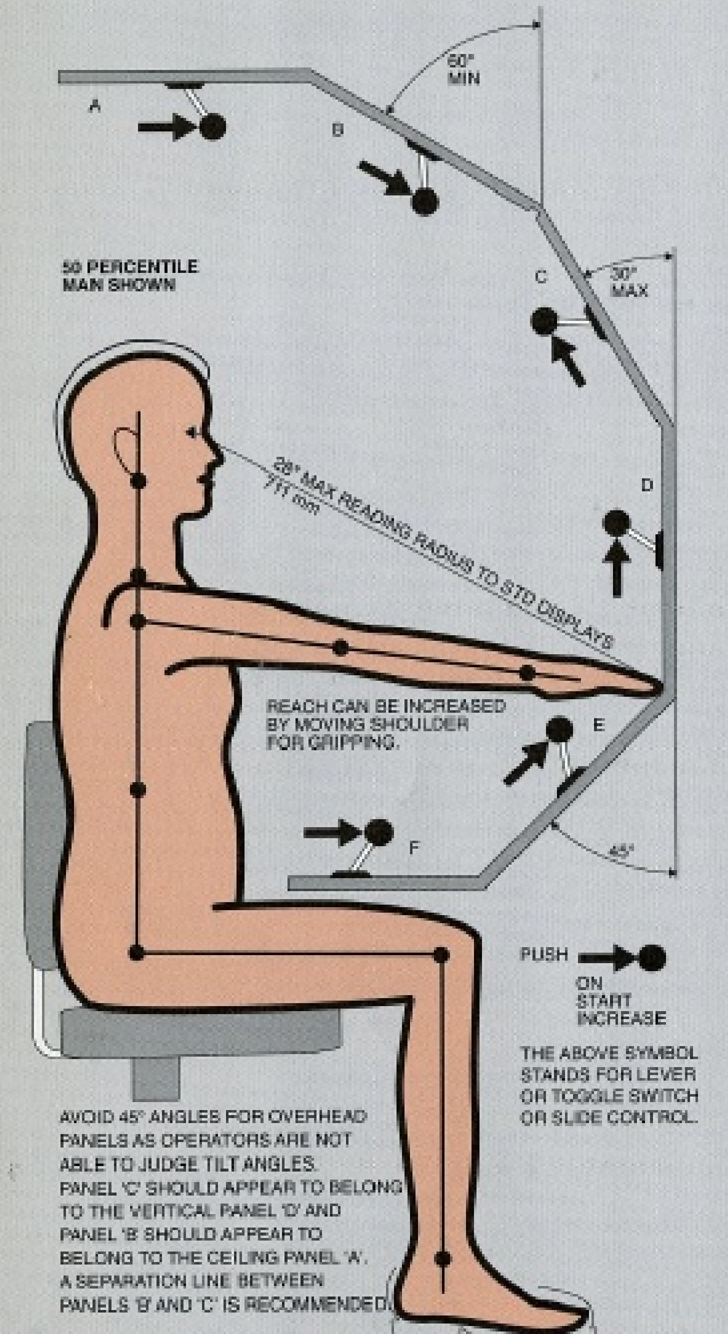
Just above this is the bicycle pedal for adults and youths and tricycle for toddlers giving the pedal sizes, the radius of the pedal, and the center line for sprocket wheels.

The portable foot pedal, foot bar, and pedal bar can be used by either foot. These are usually for machine tools.

Direction of Operations

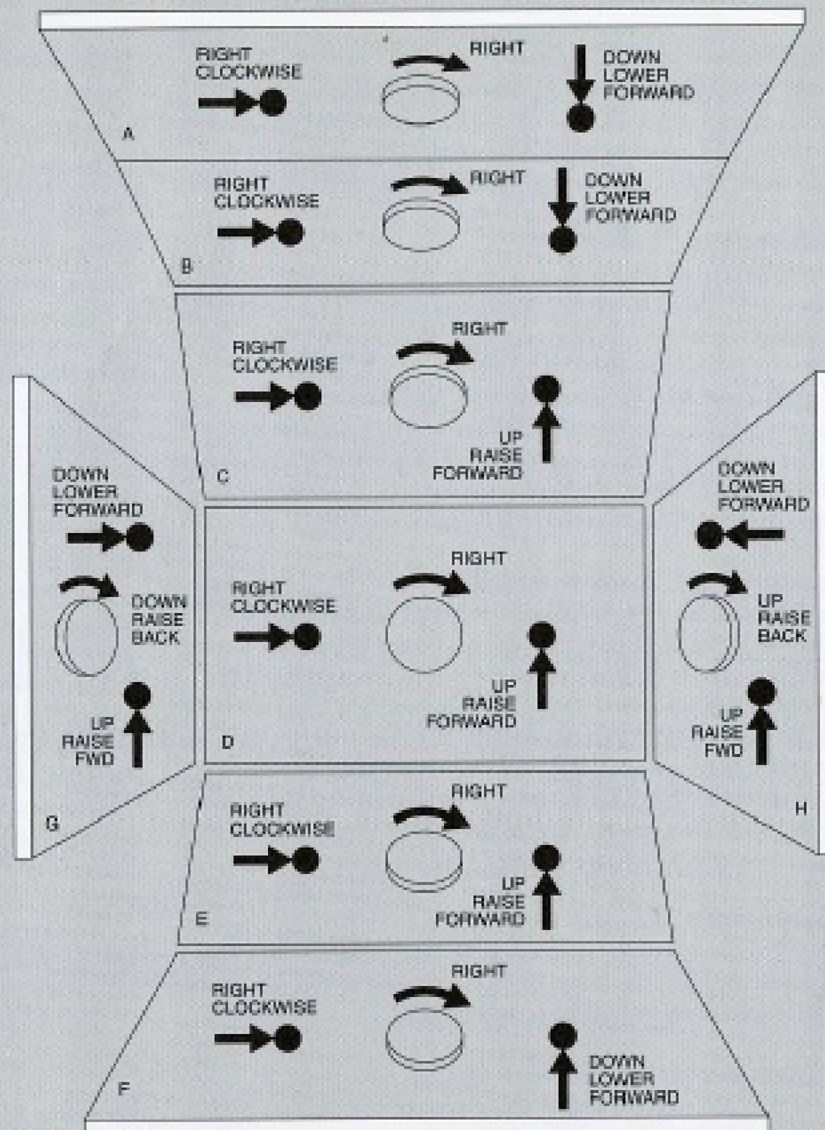
This drawing clearly lays out the directions in which operations are performed while sitting at control panels. Note that the direction of a movement varies with the location of the panel on which it is mounted.

Data in this section have been adapted from Humanscale 4/5/6, *1981; Dreyfuss, 1960; and MIL-STD 1472C, 1981.*



THE ABOVE SYMBOL STANDS FOR LEVER OR TOGGLE SWITCH OR SLIDE CONTROL.

AVOID 45° ANGLES FOR OVERHEAD PANELS AS OPERATORS ARE NOT ABLE TO JUDGE TILT ANGLES.
PANEL 'C' SHOULD APPEAR TO BELONG TO THE VERTICAL PANEL 'D' AND PANEL 'B' SHOULD APPEAR TO BELONG TO THE CEILING PANEL 'A'.
A SEPARATION LINE BETWEEN PANELS 'B' AND 'C' IS RECOMMENDED.

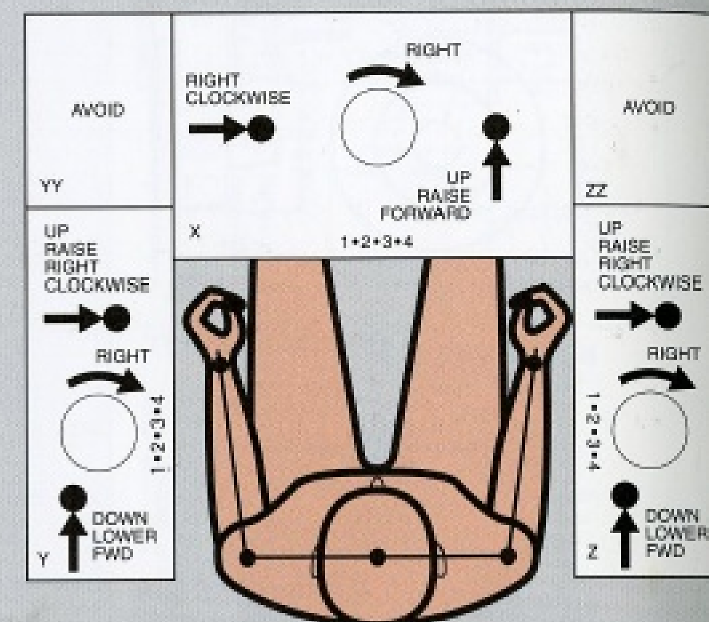


THESE TITLES CAN BE ADDED TO ALL THE ABOVE ROTARY CONTROLS AND ARE UNIVERSAL EXCEPT LIQUID AND GAS VALVES WHICH ROTATE CLOCKWISE TO SHUT OFF.

THESE TITLES CAN BE ADDED TO ALL THE ABOVE SLIDING OR ROCKING CONTROLS.
EXCEPTION: IN THE UNITED KINGDOMS SWITCHES GO UP FOR "OFF".

SIDE PANELS 'G' AND 'H' ANGLE 135° WITH 24"/610 WIDE CENTER PANEL AND 120° WITH 36"/915 WIDE CENTER PANEL 'D.'

IF OPERATOR ROTATES HIS OR HER BODY PANELS 'Y' AND 'Z' OR 'G' AND 'H' MUST HAVE IDENTICAL LAYOUT OF CONTROLS AS THE CENTER PANEL 'X' OR 'D.'
AVOID USE OF PANELS 'YY' AND 'ZZ' AS RIGHT- AND LEFT-ACTUATED CONTROLS LEAD TO AMBIGUITY.
LOCATE ALL CONTROLS IN FRONT OF OPERATORS' SHOULDERS.
HORIZONTAL PANELS MAY BE TILTED UPWARD 30°.
SIDE PANELS ARE BELOW ARMRESTS. CENTER PANEL IS TABLE HEIGHT OR ABOUT 10 OR 11" ABOVE SEAT FOR LEG CLEARANCE.
AUTOMOTIVE TYPE DASH WOULD FOLLOW RULES ON PANEL 'D.'
PUSH AND PULL CONTROLS USUALLY PULL FOR 'ON' OR 'INCREASE' AND PUSH FOR 'OFF' OR 'DECREASE.'



SEQUENTIAL ORDER FOR RELATED CONTROLS IS INDICATED ON PANELS 'X,' 'Y' AND 'Z' WITH NUMBERS 1•2•3•4
ADDITIONAL TITLES "ON, START, INCREASE AND CLOCKWISE" CAN BE USED SEE NOTES TO THE LEFT FOR THE WRAP AROUND CONSOLE
TITLES FOR OPPOSITE DIRECTIONS ARE LISTED BELOW:

CLOCKWISE	COUNTERCLOCKWISE
RIGHT	LEFT
RAISE	LOWER
FORWARD	BACKWARD
DOWN	UP
ON	OFF
START	OFF
INCREASE	DECREASE OR OFF

DIRECTION OF OPERATION FOR MANUAL CONTROLS

THE ENVIRONMENT

NOISE

Noise is unwanted sound. If the noise is very loud, it may damage the ear. Hearing loss due to the noise of man-made equipment is an "industrial disease."

Noise is measured in decibels (dB). The formula is:

number of dB = $20 \log(\frac{P_1}{P_2})$

where P_1 = sound pressure under consideration and P_2 = reference sound pressure, based on the lowest audible sound pressure in young men. Increasing the sound pressure 10 times increases the loudness by 20 dB.

Pure tones are sounds with a single frequency; however, most sounds contain overtones.

Sounds are characterized and differentiated according to the following variables:

- Pitch, which varies according to frequency. (Pitch also affects loudness.)
- Loudness, or intensity (also affects pitch).
- Timbre, or quality (e.g., musical instruments are identified by their timbre).
- Tone, characterized by a regular repeating wave pattern.
- Pure tone, produced by a single frequency.
- Complex tone, produced by several different frequencies.
- Noise, characterized by irregular wave patterns.
- White noise, characterized by a continuous spectrum of a wide range of frequencies.
- Pink noise, similar to white noise, but the spectrum declines as a function of frequency at a rate of 3 dB per octave.

The most annoying sounds include loud sounds above 60 dB, which can sometimes cause involuntary stomach contractions. Others are characterized by:

- Increasing loudness of pitch.
- High pitch.
- Long duration of loudness or high pitch.
- Modulations—that is, irregular variable sounds.
- Pure tones (8192 Hz the most, and 256, 512, 1024 Hz the least).

Noise has the following effects on humans, which can, in turn, affect the higher mental processes:

- Nervousness.
- Irritability.
- Fatigue.

Noise can sometimes be useful. It helps us detect when things are not operating correctly; for example, we can hear a automobile's engine trouble. Because of noise, we may detect conditions that require emergency actions.

Noise can be minimized by the following means:

- Relocating the source.
- Designing acoustically (consider the proportioning of rooms).
- Applying acoustical mediums, for sound absorption.
- Applying damping materials, to reduce vibrating metal.
- Shock-mounting mechanical drives, etc.
- Creating sound barriers.
- Providing personal protection devices (ear plugs, muffs, etc.).
- Masking (e.g., music can conceal kitchen noises).
- Keeping ventilation fans from exceeding 55 ft per second (16.8 m/s) tip speed and air velocity below 1500 ft per minute (27,432 m/s).

Hearing Activity and Ranges

In 1882, when the volcano Krakatoa, near Sumatra, blew up, people heard it 1000 miles away. Of course, thunder can also be heard many miles away. Note also the following:

- The highest frequency reported audible was 100,000 Hz.
- The lowest frequency reported audible was 5 Hz.
- Sound at 160 dB kills small animals.
- The threshold (upper limit) of pain to the ear is 140 dB.
- Sounds that reach the threshold of feeling are about 5 billion times the energy of a whisper.
- Sirens and mechanical devices can be heard for 5 miles.
- Musical range is about 15–20,000 Hz; the ear's greatest sensitivity range is 500–4000 Hz.
- Sound that is felt but not heard is 1–30 Hz.
- Humans can hear air molecules hitting one another in a perfectly anechoic room.
- The human voice can be heard 5 miles away under ideal conditions.
- The threshold of detectability is 5–10 dB (sounds are heard, but words are not distinguishable).
- The threshold of perceptibility is 13–18 dB (sounds of words do become distinguishable as words).
- The threshold of intelligibility is 17–21 dB (words in combination convey meaning).
- Visual stimulus can affect auditory acuity.

Hearing loss progresses with age.

- A child can hear 20,000 Hz.
- At the age of 30, one can hear only up to 15,000 Hz.
- At the age of 50, only up to 13,000 Hz can be heard.
- Hearing loss increases at a constant rate with advancing age, from a minimum of 2% to 3.5% per year (based on pitch).
- With increasing age and a 45-dB loss of hearing ability, it will be difficult to understand direct conversation.
- With a 65-dB loss of hearing ability, it becomes difficult to hear over the phone.

Voice Measurements

The voice range is about 125–5000 Hz. In speech, the most powerful sound waves are carried by frequencies below 1000 Hz.

- The average frequency of the man's voice is 128 Hz.
- The average frequency of the woman's voice is 256 Hz.
- SIL (Speech Interference Level) varies from 600 to 4800 Hz.

Noise Levels and Thresholds

Intermittent noises at 105 dB can cause hearing loss, and continuous noises at a 94-dB level can also cause hearing loss. Temporary deafness can result from noises of 100 dB. Prolonged exposure to noise of 80 dB can cause fatigue. The interference level for conversation is 45 dB. Causes of noise, environments in which noise has been measured, and specified noise limits are listed in the table below, according to decibel level.

Noise Sources and Settings	dB
Ram jet, turbojet (7000-lb thrust)	120–170
75-piece orchestra, pipe organ, shotgun, large pistol	145
Siren (100 ft), small aircraft	136
Drop hammer, submarine engine room (at full speed)	100–130
Hydraulic press (3 ft)	128
Rivet gun (4 ft)	102–128
Piano, boiler room (maximum)	126
Pneumatic chipping hammer	107–123
Thunder overhead, painfully blaring radio	110–120
Pin router	104–116
Circular saw	100–116
Multiple sandblast unit	115
Snowmobile	106–113
Jet engine test-control room	112
Automatic punch press (3 ft)	110
Hand forming sheet metal, trip and speed hammer	100–110
Twin-engine airplane, 4-ft loom, automobile on highway	110
Punch press	96–108
Chipping hammer (3 ft), woodworking shop	107
Band saw on sheet metal	106
Airliner interior	105
Cutoff saw (2 ft), wood planer	104
Weaving room	102
Annealing furnace (4 ft), shouting voice	100
Railroad car, subway train	95–100
Air drill	92–100
Can manufacturing plant	98
Automatic lathe (3 ft)	97
Public-address system	90–96
Air compressor	92
Spot welding	88–92
Heavy truck (20 ft)	92
City bus, sports car, forge, train whistle (500 ft)	90
Outboard motor (10 horsepower, at 50 ft)	88
Small truck accelerating (30 ft)	85
Noisy automobile, loud radio at home	80
Average factory, light truck in city (20 ft)	78
Heavy traffic (25–50 ft)	76
Automobiles (20 ft)	75
Average automobile (20 ft), conversation in a crowd	70
Tolerance limit for restaurants, conference at 4–5 ft table	68
Average traffic (100 ft)	67
Large telephone exchange, accounting office	65
Conversational speech (3 ft)	62
Normal conversation, department store	60
Tolerance limit for meeting room (with sound amplification)	58
Quiet street, vacuum cleaner, banks, stores, restaurants	50
Light traffic (100 ft)	47
Business office, ocean liner	45
Average residence	43
Quiet office, auditorium, classroom, low street noise	40
Hospital, sailboat, quiet radio	35
Quiet residence, turning newspaper pages, recital hall	30
Recording studio, broadcast studio	25
Whisper (5 ft), quiet garden	20
Usual hearing test in schools	15
Movie sound studio	10
Threshold of hearing (young ears)	0

MECHANICAL VIBRATION

Body damage has been caused by 30–50 Hz (e.g., percussion or hammer-type tools) and by 800 Hz (e.g., vibrating rotary tools).

Damage effects include peripheral vascular disease, injury to nerves and other soft tissues, and damage to bones and joints.

Symptoms of Raynaud's Disease are numbness, coldness, stiffness, parenthesic (tingling sensation of the skin) sensory perception at the fingertips, and an inability to hold objects; and in advanced cases, cyanosis ("dead" or "white" hand or finger condition), which is aggravated by cold environments.

Increasing intensities of vibration can produce distraction, irritation, nausea, unendurable discomfort, and, under continued exposure, trauma or injury.

Vibrations of 10–200 Hz, far below levels that affect machine performance, are annoying or harmful to humans.

Safe levels are difficult to define, since sensitivity is a blending of physiological and psychological responses. Various points of the body have more or less sensitivity in various ways. The sensitivity of the fingers and the hand is acute. The eyes, as well as certain organs, are very sensitive. Long exposure to 30 Hz of vibration can cause nausea because of the effect upon the ears. Binocular visual acuity (depth perception) is greatly affected by vibrations of 25–40 Hz and 60–90 Hz.

Low-frequency vertical vibrations can reduce reading speed and require increased illumination.

Reflex actions can be diminished or completely suppressed by certain vibrations. A standing person is most sensitive to vertical vibration; a seated person to vertical and transverse vibration. A prone or supine person is very sensitive to longitudinal vibration, while transverse vibrations can be pleasant.

Natural frequencies for various parts of the body are as follows:

Part of Body	Hz
Eardrums	16–20,000
Skull	300–400
Lower jaw (with respect to skull)	100–200
Head (with respect to body)	20–30
Eyeball	60–90
Hand	30–40
Whole body (standing)	5–12
Pelvis	5–9
Whole body (prone or supine)	3–4
Head and shoulders (transverse)	2–3
Body seated on cushion	2–3

Age

Sensitivity to vibration diminishes with age, particularly after age 50.

Sex

Women are more susceptible to pain and swelling of the hands when using electrical tools for long periods. Exception: some people appear to be "allergic" or more sensitive to vibration than others.

Vibration can be minimized in several ways:

- Shock-mounting of equipment.
- Use of a seat cushion; the suspension should have a natural frequency of walking (1–1.5 Hz).
- Installing floor padding.
- Altering vibration patterns of mechanical equipment.

Typical Vibration Frequencies in Hand-held Tools are:

Tool	Hz
Dental drill (air)	1500–2000
Tool-post motor	800
Production hand grinder	350–400
Portable electric saw	350
Portable hand grinder	280–350
Hand polisher, reciprocating	250
Production hand drill	230–225
Electric shaver	200
Shaper, hand-fed	100–175
Portable circular saw	100–120
Outboard motor propeller	50–75
Hand saber saw	50–60
Household appliances	30–60
Pneumatic tools	30–50
Portable hand drill	30–40
Rotary impact drill	30–35
Rotary hand sander, polisher	16–33
Electrical hedge trimmer	12–15

HUMAN VS. MACHINE

A consideration of human versus machine capabilities yields a number of observations:

Advantages of Humans	
Detection	Can detect a wide range of signals.
Perception	Can see through complex situations.
Flexibility	Can shift attention rapidly.
Judgment	Can use inductive reasoning, have hunches.
Reliability	Can perform under adverse conditions.
Eye	Can see with extreme efficiency (visual acuity).
Eye/Brain	Can make logical distinctions.

Limitations of Humans	
Accuracy	Susceptible to constant and variable errors.
Speed	Time is needed for decision and movement.
Force	Depends on body part in use and level of fatigue.
Computation	Slow, inaccurate.
Decision-making	The optimum strategy is not always chosen.
Information	Overloading, stress, and boredom affect performance.

Advantages of Machines	
Speed	Can be rapid.
Accuracy	Can be at a high level.
Simultaneity	Can accomplish several tasks, including complex ones, at the same time.
Repetition	Especially useful for repetitive tasks.

MOTION

A merry-go-round rotates at about 2 revolutions per minute (rpm). At more than 2 rpm, the semicircular canals of the inner ears, which control balance, can develop canal sickness, leading to pallor, sweating, nausea, drowsiness, apathy, and difficulty in walking. From 2 to 5 rpm, the average person can develop one or more symptoms. At more than 5 rpm, all symptoms could affect someone seriously enough to affect his or her safety. A combination of G forces (measurements based on acceleration due to gravity) and body motion will increase the discomfort. Unexpected directions are experienced.

The effects of accelerating forward in a sitting position (transverse G) are listed according to G forces in the following:

2G	Visual acuity is reduced.
4G	Major movement of the body is difficult.
8G	Respiration is difficult.
10G	The head cannot be held up or the limbs moved.
12G	Breathing requires mechanical help.
14G	Vision fails.

The effects of accelerating upward in a sitting position (positive G) are as follows:

2G	Visual acuity is reduced.
4G	Peripheral blindness sets in and limb movement is difficult.
5G	Temporary blindness sets in, with loss of body control.
6G	Unconsciousness results.

The effects of accelerating downward in sitting position (negative G) are as follows:

2G	Vision is reduced and head pains result.
3G	Conjunction hemorrhage and mental confusion result.
4G	Hemorrhage and retinal bleeding are likely.

Some tolerance limits for positive and negative forces are as follows:

Positive		Negative	
5G	20 sec	5G	0.5 sec
10G	2 sec	10G	0.01 sec
20G	0.15 sec		

TEMPERATURES

Humans can survive in a narrow range of temperatures. High temperatures can dehydrate and destroy living tissue, and low temperatures can stop essential circulation and stop function. Safe temperature limits depend on one's contact with air, water, and solids. First, consider the following normal temperatures, measured at various points on the body:

Skin of calf and foot	80–83°F (26.7–28.3°C)
Skin of chest	94–93°F (34.4–35°C)
Skin of waist	95–97°F (35–36.1°C)
Mouth	98.6°F (37°C)
Rectum	99.6°F (37.6°C)

Readings that represent abnormal ranges for the human body are as follows:

Unusually low	96–98°F (35.6–36.7°C)
During exercise	100–104°F (37.8–40°C)
Fever level	100–106.5°F (37.8–41.4°C)
Fatally high	Above 107.5°F (41.9°C)

Human skin is extremely sensitive. The lighest skin sensation has been recorded as the touch of a bee's wing falling on a cheek from a distance of 0.39" (10 mm). The primary skin sensations are pain, cold, warmth, and pressure; other sensations include moistness, ticklishness, itchiness, and roughness.

Skin temperatures, measured at hands, feet, or neutral skin zones, can be characterized according to the following data:

Hands	
Numb	50°F (10°C)
Painfully cold	50–59°F (10–15°C)
Tolerably cool	59–68°F (15–20°C)
Feet	
Numb	55°F (12.8°C)
Painfully cold	55–64°F (12.8–17.8°C)
Tolerably cool	64–73°F (17.8–22.8°)
Skin	
Cool	88°F (31.1°C)
Comfortably cool	91°F (32.8°C)
Comfortable	93°F (33.9°C)
Warm	94°F (34.4°C)
Unpleasantly warm	96°F (35.6°C)
Hot	98°F (36.7°C)

Solids or water of different temperatures coming into contact with the skin can be characterized as follows:

Severely cold (tissue damage)	Below 32°F (10°C)
Cool solids	37–54°F (2.8–12.2°C)
Cold water	Below 65°F (13.3°C)
Cool to tepid water	65–90°F (13.3–32.2°C)
Warm water	90–98°F (32.2–36.7°C)
Warm solids	91–95°F (32.8–35°C)
Hot water	98–105°F (36.7–40.6°C)
Very hot water	105–115°F (40.6–46.1°C)
Scalding water	Above 115°F (46.1°C)
Burning (tissue damage)	120–140°F (46.1–60°C)
Causes 2nd-degree burn in 60 sec	160°F (71.1°C)
Causes 2nd-degree burn in 30 sec	180°F (82.2°C)
Causes 2nd-degree burn in 15 sec	212°F (100°C)

An environmental temperature of 120°F (48.9°C) is the maximum that the body can tolerate for one hour. Temperatures of the immediate environment will affect people as follows:

Tolerability/Response Category	Environmental Temperature
16-min maximum nude exposure	32°F (0°C)
1-hr maximum nude exposure	40°F (4.4°C)
Stiffness of extremities	50°F (10°C)
3-hr maximum nude exposure	60°F (15.6°C)
Winter comfort zone	63–71°F (17.2–21.7°C)
Most comfortable	63–75°F (17.2–23.9°C)
Summer comfort zone	65–75°F (18.3–23.9°C)
Range for light work	65–80°F (18.3–26.7°C)
Physically fatiguing	75°F (23.9°C)
Maximum for good performance	80°F (26.7°C)
Mentally slowing	85°F (29.4°C)
Maximum for long exposure	90–94°F (32.2–34.4°C)
Tolerable for 1 hr	120°F (48.9°C)
Tolerable for 30 min	160°F (71.1°C)
Tolerable under 8 min	240°F (115.6°C)
Tolerable under 10 sec	500°F (260°C)

Temperatures higher than the following maximum allowable readings are destructive to human tissue:

Hot tub	110°F (43.3°C)
Water	115°F (46°C)
Steambath	120°F (48.9°C)
Metal (held)	122°F (50°C)
Metal (contact with)	140°F (60°C)
Hot air (e.g., dryer)	140°F (60°C)
Nonmetal (held)	144°F (62°C)
Nonmetal (contact with)	185°F (85°C)

CHEMICAL HAZARDS

Toxic materials affect living cells to various degrees, depending upon such things as temperature, their cumulative effects and delayed reactions, their concentration, and when and how exposure occurs. Of course, personal health and individual resistance are also factors.

Chemical agents can harm human beings in three ways:

1. Inhalation by contact or absorption.
2. Contact by absorption through the skin.
3. Ingestion by contact or absorption through the stomach and intestines, etc.

The first two occur most often in industry. The third applies to a poison and occurs frequently in the home. Harmful materials are usually expelled from the body by exhalation, evacuation, and urination; sometimes perspiration does this. Some chemicals can cause rapid death; some, like lead, can be stored and accumulated in body tissues.

There are three types of toxic damage:

1. Acute: resulting from rapid absorption with severe damage, whether delayed (e.g. cancer) or not.
2. Subacute: resulting from repeated exposures of hours or days.
3. Chronic: resulting from continuous absorption and accumulation.

A rough, relative listing of probable lethal doses follows:

Extremely toxic	1 grain (.065 g) taste
Highly toxic	1 teaspoon (4 cc)
Moderately toxic	1 ounce (30 g)
Slightly toxic	1 pint (.473 L)
Practically nontoxic	1 quart (.946 L)
Relatively harmless	More than 1 quart

Common industrial chemicals can damage various parts of the body. Some examples are:

Brain or Central Nervous System Damage:
Acetalaldehyde, Benzene, Butyamine, Carbon disulfide, Carbon tetrachloride, Dimethylaniline, Hydrogen sulphide, Lead, Manganese, Mercury, Nitrobenzene, Tetraethyl lead, and Thallium.

Eye Damage:
Acetic anhydride, Acrolein, Benzyl chloride, Butyl alcohol, Cresol, Hydroquinone, and Quinone.

Upper Respiratory Mucous-Membrane Damage:
Acetaldehyde, Acetic anhydride, Acrolein, Butyl alcohol, Chromium, Dimethylsulfate, Hydrogen sulphide, and Ozone.

Lung Damage:
Allyl chloride, Asbestos, Beryllium, Crystalline silica, Chromium, Dichloroethyl ether, Hydrogen sulphide, Mica, Nickel, Nitrogen dioxide, and Talc.

Heart Damage:
Aniline.

Liver Damage:
Carbon tetrachloride, Chloroform, Cresol, Dimethylsulphate, Perchloroethylene, Toluene, Trichloroethylene, and Vinyl chloride.

Kidney Damage:
Chloroform, Dimethylsulphate, and Mercury.

Blood Damage:
Aniline, Arsenic (as Arsine), Benzene, Carbon monoxide, Nitrobenzene, and Toluene.

Skin Damage:
Butyl alcohol, Nickel, Phenol, and Trichloroethylene.

RADIATION HAZARDS AND THE SPECTRUM

Today people are interested in knowing more about radiation hazards. There are three basic kinds of hazardous radiation.

1. Ionizing radiation (alpha, beta, gamma and x-rays).
2. Non-ionizing radiation (radio waves, microwaves, infrared).
3. Visible light (red, orange, yellow, green, blue, violet).

Alpha and beta waves can heavily damage human tissue. Gamma and x-rays can cause physical damage in living things. Radio waves, microwaves, infrared rays, and electric power lines carrying alternating current can cause physical damage. The unit of measure of a radiation dose is a *rem* (roentgen equivalent man). Many natural radiations are so low that a millirem, abbreviated *mrem*, is used.

Average radiation doses per year per person are as follows:

Source	mrems/yr	% of Total
Terrestrial rocks, soil, water, etc.	57.00	28.10
From space, solar, and cosmic	43.00	21.20
Phosphates, artificial fertilizers	5.00	2.50
Nuclear fallout (testing)	5–8.00	4±
Nuclear energy, generated electricity	0.28	0.14
Medical treatments, x-rays, etc.	90.00	44.30
Consumer products, watch dials, etc.	.03	.01
Total	203.00	100.00

Note: About one-half the average American dose comes from man-made sources.

Radiation workers are allowed 5000 mrems per year for normal operations. A 200,000-rmem dose received in a few minutes will cause nausea, vomiting, and diarrhea. A 500,000-mrem dose in a few minutes will produce the same symptoms and will kill half of those exposed to that dose in less than two months. Larger doses will kill everyone quickly.

COLORS

Newton passed light through a prism and separated it into colors by refraction. *Spectrum* is the Latin word for the rainbow image: red, orange, yellow, green, blue, and violet with no distinct boundaries between the colors. Later, it was found that infrared ran below the red on the spectrum (*infra* is Latin for *below*). Still later, ultraviolet rays were found above the violet (*ultra* is Latin for *beyond*).

Color Coding for Road Safety

Colors are used as signals to motorists in the following ways:

- Red is for stop (if clear: go right, in some states).
- Orange is for caution and for construction advisory.
- Green is for go.
- Yellow is for safety zones.
- Blue is for school zones.

Color Coding Used by Railroads

Standards in the railroad industry include these uses of color:

- Red means "danger" and "stop."
- Purple means "stop."
- Yellow means "proceed with caution."
- Green means "all clear, proceed."
- Blue means "caution, people are working."

Color Coding of Dangerous Products

Colors are assigned to labels on poisons and other hazardous materials as follows:

- Red letters on white are for poisons, explosives, and poison gases.
- Black letters on green are for compressed gases.
- Black letters on red are for flammable liquids and fireworks.
- Black letters on yellow are for flammable solids and oxidizing materials.
- Black letters on white are reserved for acids.

Color Coding for Industrial Safety

The following colors serve to encode hazards in work settings:

- Red is used for fire protection equipment and containers of flammable liquids, on lights at barricades, and for stop controls on machinery.
- Red and white appear on railroad crossing gates.
- Orange is used as an alert, and is used on dangerous parts of machinery that can cut, crush, shock, etc.
- High-visibility yellow is for caution, and is used in traffic lanes; black stripes over yellow is used for special warnings.
- Green is for safety and is used on first-aid equipment.
- Blue stands for caution and is used on equipment under repair (usually applied as a tag meaning "do not use.")
- Purple is reserved for radiation hazards.
- Black and white is for traffic lanes and housekeeping markings.

Color Coding for Pneumatic Systems

Pneumatic equipment should carry the following color signals:

- Black is for intensified pressure (induced by booster).
- Red is for supply pressure (pressure of actuating air).
- Intermittent red is used for charging pressure and reducing pressure.
- Yellow is for metered flow (control flow rate).
- Blue is for exhaust (return of power-actuating medium to atmosphere).
- Green is for intake (subatmospheric pressure, e.g., intake on compressor).
- Use no color on inactive piping (air pressure in circuit, not functional at phase represented).

Color Coding for Hydraulic Systems

Hydraulic equipment should carry the following color signals:

- Black is for intensified pressure (induced by booster).
- Red is for supply pressure (pressure of power actuating fluid).

- Intermittent red is for charging. It is also used for reduced pressure.
- Yellow is for metered flow (fluids at controlled flow rate).
- Blue is for exhaust (returned power-actuating fluid to reservoir).
- Green is for intake (subatmospheric pressure, e.g., on intake side of pump.) Green is also reserved for drains (return of leakage control actuating fluid to reservoir).
- Use no color for inactive pipes (fluid within system but not functioning at phase represented).

Color Coding Pipes for Identification

There are colors assigned, as follows, for plumbing systems and the like:

- Red is reserved for sprinkler piping mains and risers.
- Orange or yellow is reserved for pipes carrying dangerous materials (e.g. acids, alkalis, chlorine gas, ammonia, sulfur dioxide) or to indicate high-temperature and high-pressure (e.g., steam, high-pressure water and air).
- Black, white, gray, or aluminum colors are for safe materials.
- Bright blue is used for materials that lessen hazards of dangerous materials (e.g., filtered water, antidotes to poisonous fumes). Use for all protective materials other than fire protection.

Color Coding Controls (U.S. Navy Radar)

The following standards are applied to naval equipment such as radar control panels:

- Red for gain (rotary control knob).
- Orange for tuning (rotary control knob).
- Yellow for range (pointer knob).
- Green for marker (finger crank).
- Blue for intensity (rotary control knob).
- Violet for focus (rotary control knob).
- White for dimmer (rotary control knob).
- Gray for bearing (finger crank).

Note: Try to limit colors to six and to incorporate shape coding as well.

Color Psychology

Colors have always been associated with emotions or assigned meanings. Here are some important examples:

- Red: fire, danger, stop, excitement, aggression, love.
- Orange: heat, orange juice, pumpkins, Halloween.
- Yellow: sun, cheerfulness, warmth, caution.
- Green: nature, vegetation, go, St. Patrick's Day.
- Blue: sky, water, coolness, victory in competition.
- Purple: mourning, royalty, sacredness, Easter.
- Gray: neutrality, the Navy, dullness, overcast day, gloom.
- White: virginity, marriage, snow (Chinese symbol of death).
- Black: mourning, formality (evening clothes).

Color Symbolism in Universities and Colleges

In the academic setting, these color relationships have been established:

- Scarlet stands for theology.
- Purple stands for law.
- Blue stands for philosophy.
- Yellow stands for science.
- White stands for arts and letters.
- Orange stands for engineering.
- Green stands for medicine.
- Pink stands for music.

Colors for Foods

Certain colors appeal to the appetite: peach, orange, clear yellow, light green, vermilion, red, tan, and brown.

Tinted colors such as pink, pale blue, or violet are best used on fancy desserts.

Since most food colors are on the warm side, warm lighting (incandescent lamps) is preferable; avoid cold illumination (cold fluorescents).

Visibility of Colors

Factors such as distance can affect the ability to read colors correctly:

- Opaque yellow is the most luminous for a great distance over snow.
- Orange and red-orange hold the attention best.
- Blue is likely to be hazy and indistinct.

Small, bright-colored lights near the threshold of visibility are easier to recognize than others:

- Red, green, and some blue lights are easiest to recognize.
- White light is the next easiest to recognize.
- Yellow and orange lights are the last to be recognized.

Some colored lights are difficult to see far away:

- Blue and green lights are impossible to differentiate at great distances.
- Yellow and orange lights are impossible to differentiate at great distances.

The Color Environment

The actual colors we perceive are not constant under all conditions, but depend on the following factors:

- Time of exposure.
- Surrounding colors.
- Previous fixated colors.
- Light sources.

Red and orange appear to advance, because rays reflected from them into the eye affect the focus of the lens and produce farsightedness. Green and blue make the eye nearsighted, hence these colors tend to recede. Yellow and purple are neutral in this effect, and neither advance nor recede.

In general, warm colors (red, pink, yellow, and orange) are most important in early years of life; in maturity blue, red, and green are dominant.

We do not all see colors the same way. People who have done color research may be aware of more colors, especially having studied the famous color-chart work of Munsel.

To the eye there are three primary forms: Pure color (any hue), white, and black. There are also a few secondary forms:

Color + white forms a tint.

Color + black forms a shade.

White + black forms a gray.

Color + gray forms a tone.

The primary colors in vision are red, yellow, green, and blue. But the primaries of light are red, green, and blue. The primaries of pigments are red (magenta), yellow, and blue (cyan).

Bright environments are best for large, dynamic settings, and strong colors are more prevalent in such bright environments. Soft, deep colors are best for places where mental and physical tasks are done. Tones appear more in temperate zones, and would wash out in tropical regions.

Colored wall surfaces may enhance the human complexion by being complementary; however, if light is reflected from these colors the complexion will suffer. White glares and soils easily; use an off-white. Gray will harmonize with any color.

Prefer toned-down color for active areas, and use stronger colors for accents or as stimuli.

It has been said that there are ten million distinguishable colors. Many people see only 8 to 12 colors. At least 25% see colors differently from the majority. Distinguishability of colors improves with practice and training. Among men, 3.5% are color-blind and cannot be relied upon to receive important color signals. Only 0.2% of women are color-blind to this degree. Colors are perceived most accurately by persons 16 to 35 years of age. Children and older people are less skillful at color discrimination, and above age 55 discrimination deteriorates very quickly. Blue content in the eye increases with age. Many people over 66 have trouble distinguishing yellow from blue.

LIGHTING

There are six basic types of lighting or light quality:

1. Direct lights should be located to prevent direct glare. Glare can be minimized by using recessed egg-crate diffusers or supplementary shades.
2. Indirect sources give a pleasant lighting effect. However, for up lighting, a white ceiling and more electrical power are required.
3. Diffused lighting is good for high ceilings. However, there exists some possibility of glare.
4. Semi-indirect fixtures offer a compromise. Use soft lighting with direct and some diffused light combined for economy of operation.
5. Transillumination carries light by clear fiber-optics to illuminate displays.
6. Backlighting can be used for some displays or for projection of displays on screens from behind.

Lighting Sources

There are many types of light sources. Here are five:

1. Incandescent light sources have reddish tints and are very pleasing. They enhance flesh tones and improve the appearance of food.
2. Fluorescent lights are straight-line tubes or are bent into circles and are usually bluish. It is best to use warm whites. Fluorescent lamps outlast incandescent lamps 3 to 4 times; less of their energy is lost in heat.
3. Black light (invisible ultraviolet light) can make fluorescent and phosphorescent paints glow. Dark environments are best.
4. Red lighting is used where dark adaptation is required. Dark adaptation is the eye's increase of sensitivity in prolonged periods of darkness. At low levels of light, the eye finds the red symbols very visible. The narrow range of red is near the center of vision, and this is another reason for its use in military equipment. White characters on a black background should appear on the instruments in normal lighting.
5. High-intensity discharge (HID) lights have a long lamp life. The following are three basic types:
   a. Mercury lights are bluish white. Being deficient in red illumination, they distort color rendition (e.g., reds and facial complexion renditions are unpleasant). Energy output efficiency is 14.6% for 400 watts.
   b. Metal halide lights are similar to mercury lights but have added halides (thallium, indium, scandium, or dysprosium), which create a white light. Energy output efficiency is 20.6% for 400 watts.
   c. High-pressure sodium light radiates across the visible spectrum with emphasis in the reds and yellows, giving a golden-white illumination beneficial for facial and food renditions. Energy output efficiency is 25.5% for 400 watts. Because of their efficiency and pleasantness, high-pressure sodium lights are replacing mercury lighting on roadways and in sports arenas. This lighting can reduce the effectiveness of red danger lights and can cause plants to start growing out of season.

Recommended Levels of Artificial Illumination

The following is a guide for minimum levels of illumination for certain tasks. The values accommodate young adults with normal and better than 20/30 corrected vision. Values in one category can be used under other categories. The first value is for foot candles (fc) for the task, the second value is for lux (lx) for the task.

Home	fc	lx
Reading, studying	30–70	320–750
Writing (with pencil)	70	570
Sewing, hand or machine (Low value is for white cloth and high value is for black cloth)	50–200	540–2150
Kitchen sink and range	70	750
Kitchen counters	50–150	540–1600
Laundry work	50	540
Workbench hobbies	70–200*	750–2150
Washer, dryer, games	30	320

* *Use if making jewelry.*

Office	fc	lx
Bookkeeping	150	1610
Typing	70	750
Filing	70	750
Conference rooms	30	320
Reception areas	20	220
Corridors	20	220
Drafting (Low value is for rough work, high value is for fine work.)	150–200	1610–2150

School	fc	lx
Chalk boards	150	1610
Desks (for study)	70	750
Drawing (art work)	70	750
Gymnasium	30	320
Auditorium	15	160

Theater	fc	lx
Lobby	20	220
During intermission	5	54
During movie	0.1	1

Industrial	fc	lx
Precision manual arc welding	1000	10,750
Extra-fine machine work and inspection	1000	10,750
Fine machine work	500	5380
Medium machine work	100	1080
Rough machine work	50	540
Sheet metal (scribing)	100	1080
Steel and sheet metal fabrication	50	540
Paint mixing and matching	200	2150
Receiving and shipping	10	110

For Instruments	fc	lx
Business machines, calculators, digital input, etc.	50–100	540–1080
Control panels, consoles	30–50	320–540
Dials	30	320
Meters	30–50	320–540
Gauges	50	540
Scales	30–50	320–540
Scales with 1/64" divisions	180	1930

Medical	fc	lx
Operating table	2500	26,850
Emergency operating	2000	21,500
Dental work	1000	10,750
Examination room	50–100	540–1080

Train	fc	lx
Dining	50	540
Reading	30	320
Aisle, steps	10	110

Levels of Illumination in Daylight

Light Condition	fc	lx
In direct sunshine (at noon)	6000–8000	64,500–87,000
In shade (outdoors at noon)	100–1000	1080–10,750
Comfortable reading (in shade at noon)	200	2150 minimum

Contrast Ratios

The following information is conservative and safe to use. Designers may deviate with grace depending on architecture, location, etc.

- Prefer matte white on a ceiling for high light reflection.
- Floors are best with about 20 to 25% reflection.
- Recommended wall reflectance is about 50 to 60%, though one wall may have a reflectance of 20 to 40% for interest or practicality.
- Machines, equipment, fixtures, desks, etc., are best with a reflectance of 20 to 40%.

A contrast ratio is the relation between the luminance of two different surfaces. High contrast ratios aid legibility; low contrast ratios give relaxing and restful conditions.

- For relaxing, prefer a maximum contrast ratio of 3:1.
- The maximum contrast ratio between a work area and the immediate surroundings should be 3:1 (e.g., the ratio of the reflectance of a page in a book and the tabletop).
- The contrast ratio between a work area and the remote surroundings is best at 5:1.
- Prefer a maximum contrast ratio of 10:1 for interiors. The contrast ratio between a clear window and an adjoining wall can reach 20:1, but this is a harsh condition.
- The normal contrast ratio outdoors is about 40:1. (This value will be exceeded by direct or reflected sunlight.)
- Black ink on white drawing paper can give a contrast ratio of 1:18, which is excellent for visibility. Reading a book with this high ratio would become tiring, so either gray the ink, tint the paper, or both.
- Typewritten letters on typing paper have a contrast ratio of 1:8.
- Writing with a soft pencil on white drawing paper has an approximate contrast ratio of 1:3.
- Minimum contrast ratio for legibility is 1:2.

Reflectance Factors

Outside and Building Materials	%
White plaster	90–92%
White structural glass	75–80
White terra cotta	65–80
Snow (new)	74
Snow (old)	64
Limestone	35–65
Concrete	40–55
Light buff brick	48
White marble	45
Dark buff brick	40
Dark red brick	30
Cement	27
Vegetation (average)	25
Sandstone	18
Blue stone (pavement)	18
Granalith (pavement)	17
Asphalt and macadam pavement	15
Gravel	13
Slate	6.7–8.0
Moist earth	7
Dark green grass	6

Cloth	%
White linen (dull finish)	81%
White cotton	65
Red cotton (diamine fast red)	44
Black cotton (diamine)	33
Blue woolen	25
Blue flannel	17.5
Blue linen (navy blue)	17
Black woolen	12
Black velvet	1.8

Paper	%
Quality white	85%
White blotting	82
White drawing	70–80
Medium quality white	75
Light gray	73
Cheap white	70
Pink	60
Buff	60
Newsprint	55
Medium gray	45
Dark gray	20
Chocolate brown	20
Olive green	15
Matte black	5
Ultramarine blue	3.5
Hard pencil line	45
Soft pencil line	25
Printer's ink (good quality)	15
Black ink	4
Black velour	0.4

Woods	%
Birch and beech	35–50%
Whitewood (plain)	45
Maple	42
Satinwood	34
Light oak	25–35
English oak	17
Walnut	16
Black Walnut	5–15
Dark oak and cherry	10–15
Mahogany	12

Glass and Plastic	%
Mirror glass	80–90%
Metabolized plastic	75–85
White structural glass	75–80
Reflective glass	20–30
Clear glass	7
Tinted glass	7
Black structural glass	5

Metallic Surfaces	%
Silver (highly polished)	90–92%
Metalized	75–85
Brass (bright)	75
Aluminum (polished)	67–70
Steel (galvanized)	69
Aluminum paint	60–70
Copper (bright)	65
Nickel (polished)	60–65
Chromium (polished)	61–62
Stainless steel (bright)	55–65
Aluminum (matte)	55–60
Brass (polished matte)	52–55
Chrome (satin)	50–55
Brass (dull)	35
Copper (dull)	35
Stainless steel	25–30
Tin plate	25–30
Steel (bright)	25
Cast or galvanized iron	25

Interior Surface Colors	%
Dull or flat white	75–90
Cream or eggshell	79
Pale pink, pale yellow	75–80
Ivory	75
Light green, blue, or orchid	70–75
Light beige and pale gray	70
Soft pink and light peach	69
Pink	64
Apricot	56–62
Tan or yellow gold	55
Light gray	35–50
Medium turquoise	44
Yellow green	45
Medium light blue	42
Old gold and pumpkin	34
Rose	29
Cocoa brown and mauve	24
Medium green and blue	21
Medium gray	20
Dark brown and dark gray	10–15
Olive green	12
Dark blue and blue green	5–10
Forest green	7
Aluminum paint	60–70

Accent Colors	%
White (diffuse)	80
Deep red	14–22
Red	21–31
Orange	38–48
Yellow	60–65
Yellow green	42–46
Saturated green	24–32
Blue	17–23
Violet purple	12–14
Red purple	16–23

Color Temperature of Various Lights in Kelvin

The Kelvin (K) is a standard black body heated to a certain color, matching a particular light source. Take 273.15 from the following values to get the Celsius scale (°C).

Light Source	°Kelvin
Light from clear blue sky	10,000–30,000
Light from hazy sky	7500–8400
Special daylight fluorescent	7500
Special filtered tungsten lamp	7450
High-speed electronic flashtubes	7000
Sunlight from overcast sky	6800–7000
Sunlight from clear sky at noon	6500
Daylight fluorescent lamp	6500
Blue flash lamp	6000
Direct sunlight at 10 a.m.–3 p.m.	6000
Direct sunlight in summer	5800
Discharge mercury lamp 400W	5690
Metal halide lamp 400W	5200
Daylight blue (flood) lamp	4800
Cool white fluorescent lamp	4000
White fluorescent lamp	3600
White reflector floods	3400
Soft white fluorescent lamp	3350
Amber flash lamp	3200
Photo flood lamps	3200–3400
Projection lamp 500W	3175
Warm white fluorescent	3100
Incandescent tungsten 1000W	3000
Incandescent tungsten 500W	2950
Incandescent tungsten 60W	2800
Incandescent house lamps	2500–3000
Candle flame	1500–1800
Red-hot metal	800–900

Colored photographic films are designed for certain color temperatures. One film is close to 6,000K for daylight use and some are 3,400K for indoor use.

Reaction Times

Reaction times vary according to different factors, as shown in the following.

By Sense Preceptor	sec
Touching	.11–.15
Temperature	.15–.22
Pain	.70–1.00
Hearing	.12–.22
Smelling	.29
Tasting	.20–1.10
Seeing	.15–.20
Eyes to focus	.165
Eyes move to 40° without focusing	.10

By Age	sec
5 years	.40
10 years	.30
20 years	.20
30 years	.22
40 years	.25
50 years	.38
55 years	.35
60 years	.50

Reaction time varies with sex: men take 0.1 second less for sound and light than women.

Reaction time varies with limbs: feet take 20% more time than hands.

The left hand, for the right-handed, takes 3% more time than the right hand.

Reaction time varies with training; with practice, it can be reduced 10%.

Reaction time varies with signal characteristics. The minimum signal period is 0.2 seconds. Short signals of 0.1 second are not good. Alerting signals can reduce reaction time up to 40%.

An illustration of total reaction time follows: A pilot sees an approaching plane through the haze:

1. The pilot detects a plane (eye moves)	0.3 sec
2. Intercepts image (perception)	0.6
3. Selects course of action (decision)	0.5
4. Pilot moves control (response)	0.3
Total reaction time	1.7 sec

If both planes are headed toward one another at 400 mph, each pilot has only 1,000 feet before a collision. That distance will be covered in the 1.7 seconds of reaction time.

APPENDIX

CONVERSION SCALES

Length Conversions

1 inch equals 25.4 millimeters (mm)

1 inch equals 2.54 centimeters (cm)

1 foot equals 304.8 millimeters

1 foot equals 30.48 centimeters

1 foot equals 0.3048 meters (m)

1 mile equals 1.609 kilometers (km)

Area Conversions

1 square inch (in^2) equals 6.45 square centimeters (cm^2)

1 square foot (ft^2) equals 0.093 square meters (m^2)

1 acre equals 0.405 hectares (ha)

Volume Conversions

1 cubic foot (ft^3) equals 0.0283 cubic meters (m^3)

1 cubic yard equals 0.764 cubic meters

1 US gallon equals 3.785 liters (1)

1 US quart equals 0.9462 liters

1 liter equals 1,000 milliliters (ml)

1 liter of water has a mass of 1 kilogram of fresh water.

Weight Conversions

1 ounce (oz) equals 28.35 grams (g)

1 kilogram equals 1000 grams

1 short (US) ton equals 0.9072 metric ton (t).

Force Conversion

1 ounce force (ozf) equals 0.728 Newtons (N)

1 pound force (lbf) equals 4.4482 Newtons

Torque of Bending Moment Conversions

1 ounce force acting at a radius in inches (oz f · in) equals 0.00706 N · m

1 pound force acting at a radius in feet (lbf · ft) equals 1.3558 N · m

Pressure or Stress Conversion

1 pound per square inch (psi) equals 6.895 kilopascals (kPa)

1 pound per square inch (psi) equals 0.006895 megapascals (MPa)

Work or Energy Conversions

Work equals force times distance. In the metric system the unit of work is the joule (J) which is defined as a force of 1 Newton displaced through a distance of 1 meter in the direction of the force (1 J equals 1 N · m)

1 mean British Thermal Unit (BTU) equals 1.055 kilo joules (kJ)

1 small calorie (cal) equals 4.187 joules (J)

1 large calorie (kcal) equals 4.187 kilo joules (kJ)

Power Conversions

Power is the rate of doing work or expending energy. The unit of power is the watt (W) and is equal to 1 joule per second (J/s)

1 J/s equals 1 N · m/s

1 BTU per hour equals 0.2931 watts

1 foot pound force per second (ft lb f/s) equals 1.356 watts

1 horsepower (hp) equals 0.7457 kilowatts (kw)

The above horsepower is defined as 550 foot lb f/s.

Time and Angle Conversion

Angles are measured in degrees except use the decimal system in place of minutes and seconds (e.g. use 6.55° not 6°30'30")

Time and degrees are the only units in the metric system not based on ten.

Temperature Conversions

The scientific unit of thermodynamic temperature in the metric system is the Kelvin (K).

1 degree Kelvin (°K) equals degrees Celsius plus 273.15°

1 degree Fahrenheit (°F) equals 9/5 degree Celsius (°C) plus 32°

1 degree Celsius equals 5/9 (Fahrenheit minus 32°)

Light Conversions

1 Foot candelas (cd f) equals 10.764 lux (lx f)

1 Foot lambert (fl) equals 3.426 candelas per square meter (cd/m).

1 Lambert equals 3183.1 candelas per square meter (cd/m)

Scales

Commonly Used Drawing Scales in the USA and their Approximate Equivalent in Metric:

1/8 full size in the USA becomes 1/10 in metric

1/4 full size in the USA becomes 1/5 in metric

1/2 full size in the USA becomes 2/5 in metric

Full size in the USA remains the same in metric

ABBREVIATIONS

adj or adjust: adjust, adjustment

alt: alternate

approx: approximate, approximately

avg: average

C: Celsius

cal: calorie

cap: capacity

℄ : center line

C.G.: center of gravity

cir: circumference

clear: clearance

cm: centimeter

CRT: cathode ray tube, TV

ctr: center

d or dia: diameter

dB: decibels

dist: distance

°: degree

eff: efficient, efficiency

e.g.: for example

elec: electric, electricity

eng: engineering

equip: equipment

f: female, force

F: Fahrenheit

fc: foot candle

ft: foot

fwd: forward

g: gram

G: gravity

hgt: height, high

horiz: horizontal

HP or Hpt: hip pivot point

hr: hour

Hz: Hertz (frequency)

IES: Illuminating Engineering Society

in or ": inch

incl: including

K: Kelvin

kcal: kilocalorie

kg: kilogram

km: kilometer

km/h: kilometers per hour

l: left

L: liter

lav: lavatory (wash basin)

lb, lbs: pound, pounds

lbf: pound force

LCD: liquid crystal display

LED: light-emitting diode

lg: length

lm: large man

lw: large woman

lx: lux

m: man, male, meter

ma: milliamperes

max: maximum

mil: military

min: minimum, minute

mL: millilambert

mm: millimeter

mo: month

mph: miles per hour

m/s: meters per second

N: Newton

no: number

opp: opposite

opt: optimum

ozf: ounce force

ppm: parts per million

%: percent

%ile: percentile

pref: prefer

r or rad: radius

rect: rectangle

ref: reference

req'd: required

rt: right

rpm: revolutions per minute

SD: standard deviation

SI: International System (metric)

SIP: seat index point

sm: small man

sq: square

SRP: seat reference point or plane

std: standard

sw: small woman, switch

sys: system

t: torque

ver: vertical

w: wide, width (breadth), woman

W: watt

wc: wheelchair, water closet (toilet)

wt: weight

yr or yrs: years, age

ANTHROPOMETRIC TERMS

Abdominal depth: the most anterior point of the abdominal curve on the midplane.

Abduct: to move away from the body axis or one of its parts.

Acromion: the highest point on the lateral edge of the shoulder bone (used for shoulder height).

Adduct: to move towards the body.

Anterior: pertaining to the front of the body.

Auricular: pertaining to the external ear.

Axilla: the armpit.

Biceps: the large muscle at the front of the upper arm; also, the large muscle at the back of the thigh.

Brow ridge: the bony ridges covered by the eyebrows.

Bustpoint: The most anterior projection of the right breast.

Buttock protrusion: the maximum posterior protrusion of the right buttock.

Calf level: the height of maximum calf circumference.

Cervicale: the largest bony bump on the spinal column in the region of the base of the neck.

Cheilion: the corners of mouth where the lips join.

Clavicle: the collarbone, linking the scapular and the sternum.

Coronal plane: any vertical plane at right angles to the midplane.

Crinion: the point in midplane where the hairline meets the forehead.

Cutaneous lip: the area between the upper lip and the nose.

Dactylion: the tip of the middle finger.

Deltoid muscle: the large muscle on the outer side of the upper arm in the shoulder region.

Distal: at the end of a body segment farthest from the trunk.

Dorsal: on the back of the hand or the foot.

Ectocanthus: the outside corner or angle formed by the meeting of the eyelids.

Epicondyle: the bony eminence at the distal end of the humerus and femur.

Extend: increase a limb angle.

External: away from the central, long axis of the body.

Femoral epicondyles: bony projections on either side of the distal end of the femur.

Femur: the thigh bone.

Flex: reduce a limb angle.

Frankfurt plane: the standard orientation of the head, determined by a line passing through the ear hole and the lower edge of the eye orbit and made horizontal.

Frontal plane: same as coronal plane.

Glabella: the most forward point in the midline of the forehead between the brow ridges.

Gluteal furrow: the furrow where the buttock joins the thigh.

Gonial angle: the obtuse angle at the back of the lower jaw.

Helix: the rolled outer part of the ear.

Humeral epicondyles: the bony projections on both sides of the distal end of the humerus.

Humerus: the upper arm bone.

Hyperextend: to overextend a limb or part of the body.

Iliac crest: the top rim of the pelvic bone.

Inferior: below or lower than another body part.

Inseam: a clothing term used to indicate the inside length of a sleeve or trouser leg.

Inion: the small bony bump at the rearmost part of the head.

Ischia: two bony tuberosities at the bottom of the pelvis that support 60% of a person's sitting weight.

Knuckle: the finger joint between the phalanx and the metacarpal (finger bone and palm bone).

Larynx: the upper part of the windpipe, containing membranes which produce vocal sounds.

Lateral: lying near or toward the sides of the body.

Lateral malleolus: lateral bony protrusion of the ankle.

Lateral vastus muscle: the large muscle running from the kneecap to the hip on the outside of the upper leg.

Malleolus: a bony projection on each side of ankle.

Mandible: the lower jaw.

Mastoid: the bony protrusion directly behind the ear.

Medial: lying near or towards the midline of the body.

Medial vastus muscle: the large muscle running from the kneecap to the hip on the inside of the upper leg.

Metacarpal: the long hand bones between the wrist and the fingers.

Metatarsal: the long foot bones between the tarsus and the toes.

Menton: the point at the tip of the chin on the midplane.

Midsagittal plane: the vertical plane dividing the body into right and left halves.

Nasal root depression: the indentation at the bridge of the nose.

Nasal septum: the membrane between the nostrils.

Navicular bone: the small bone in the hand distal to the bend of the wrist on the thumb side.

Occipital region: the back of the head.

Occular: pertaining to the eyes.

Occiput: a bone forming the posterior base of the skull.

Olecranon: the bony tip of the elbow.

Omphalion: the center point of the navel.

Orbit: the eye socket.

Palmar: pertaining to the palm (inside) of the hand.

Patella: the kneecap.

Pelvis: the bones of the pelvic complex.

Phalanges: the bones of the fingers and toes.

Philtrum: the groove between the lip and the nasal septum.

Plantar: pertaining to the soles of the feet.

Popliteal area: the area in back of the leg behind the knee.

Posterior: the back of the body.

Pronasale: the most anterior point of the nose.

Proximal: the end of a limb nearest the trunk.

Radius: the bone in the forearm on the thumb side.

Ramus: the vertical portion of the lower jaw bone (mandible).

Sagittal: pertaining to the midsagittal plane of the body or a parallel plane.

Scapular: the shoulder blade.

Scye: a clothing term designating the armhole of a garment.

Sellion: the point of greatest indentation of the nasal root depression.

Sphytion: the most distal extension of the tibia on the medial side of the foot.

Spine: the backbone, composed of vertebrae.

Sternum: the breastbone.

Stomion: the point of contact between the upper and lower lips on the midplane.

Superior: above or higher.

Supra: prefix designating above or on.

Tarsus: the collection of bones in the ankle joint.

Thyroid cartilage: the "Adam's apple" on men.

Tibia: the shin bone.

Tragion: the point located at the notch just above the tragus of the ear.

Tragus: the small flap of flesh in front of the earhole.

Transverse plane: the horizontal plane through the body perpendicular to the mid and frontal planes.

Triceps: the muscles at the back of the upper arms.

Trochanterion: the tip of the bony lateral protrusion of the proximal end of the thigh bone.

Ulna: one of the bones in the forearm on the little finger side of the arm.

Umbilicus: the depression in the abdomen (belly button) where the umbilical cord was attached to the mother.

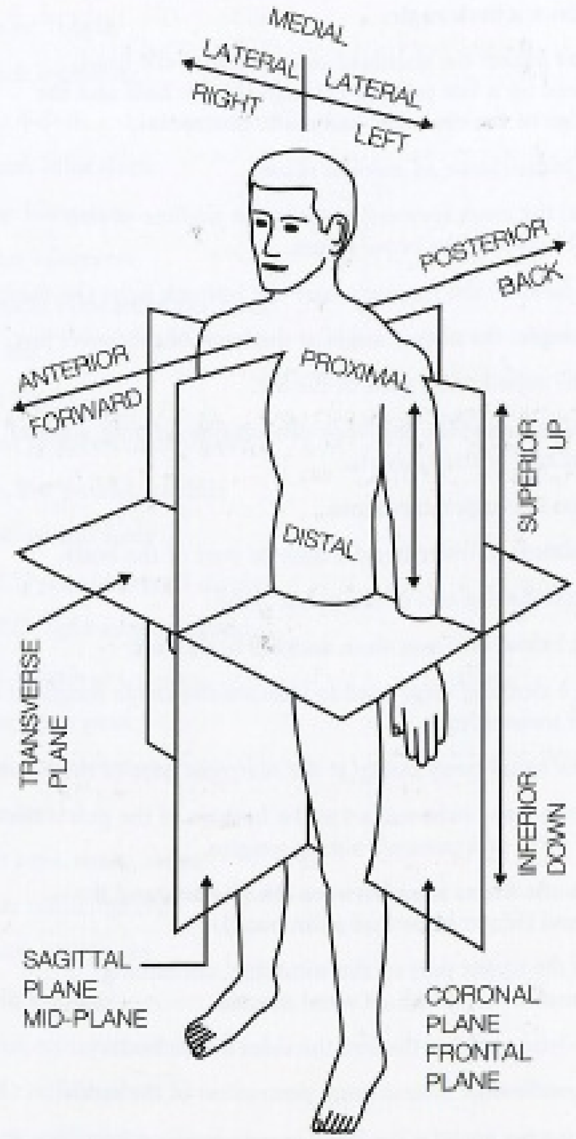
Ventral: pertaining to the front side of the trunk.

Vertebra: a bone of the spine.

Vertex: the top of the head.

Waist: the area, generally, at the belt line, or the "natural waist."

Zygomatic arch: the bony arch running along the side of the cheek almost to the ear.



ANATOMICAL PLANES AND ORIENTATIONS

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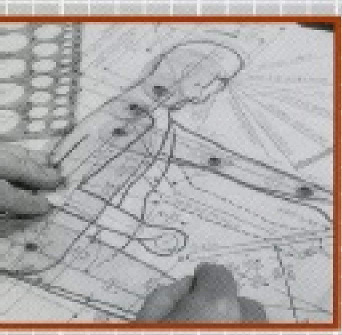
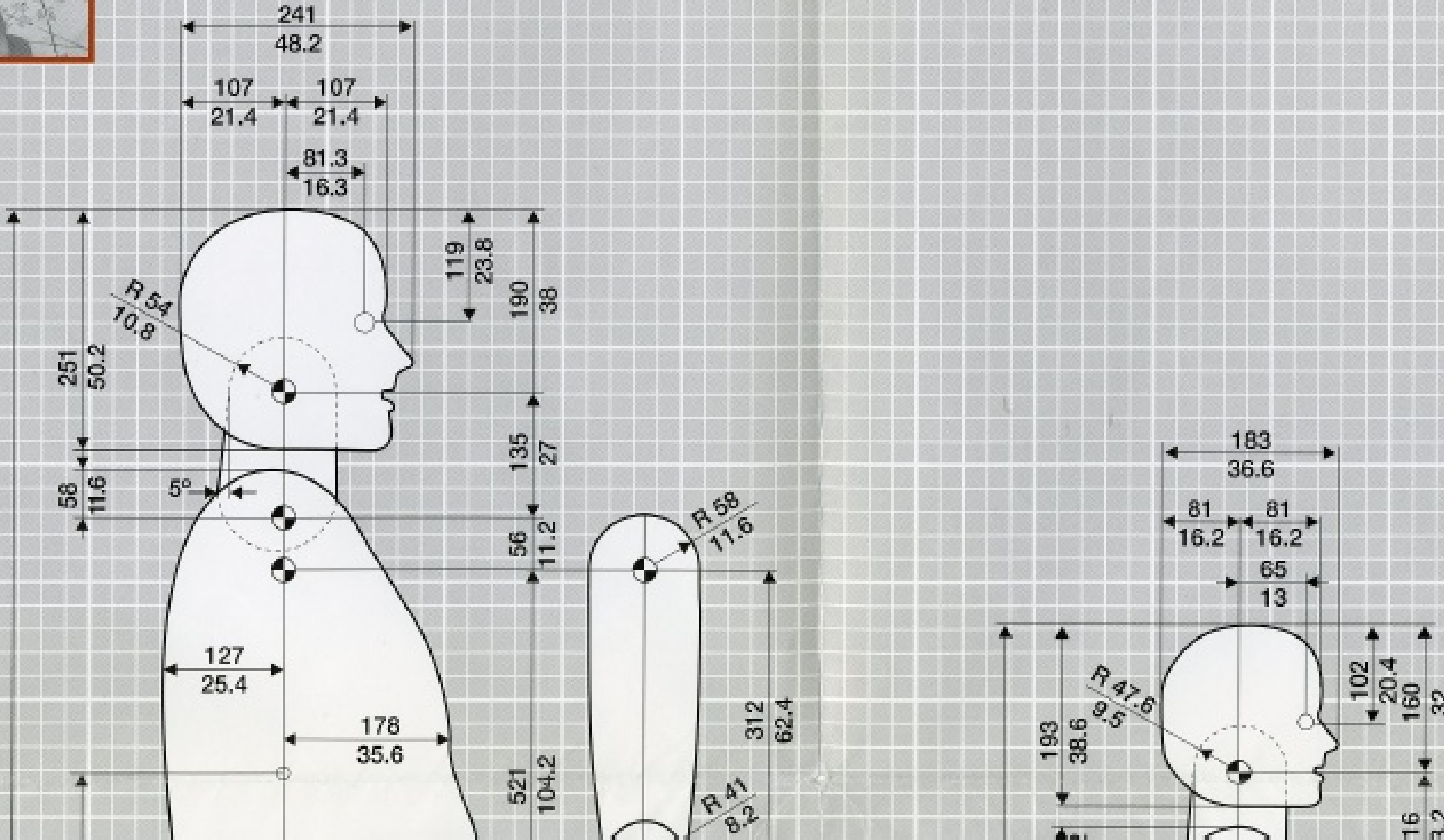
INDEX

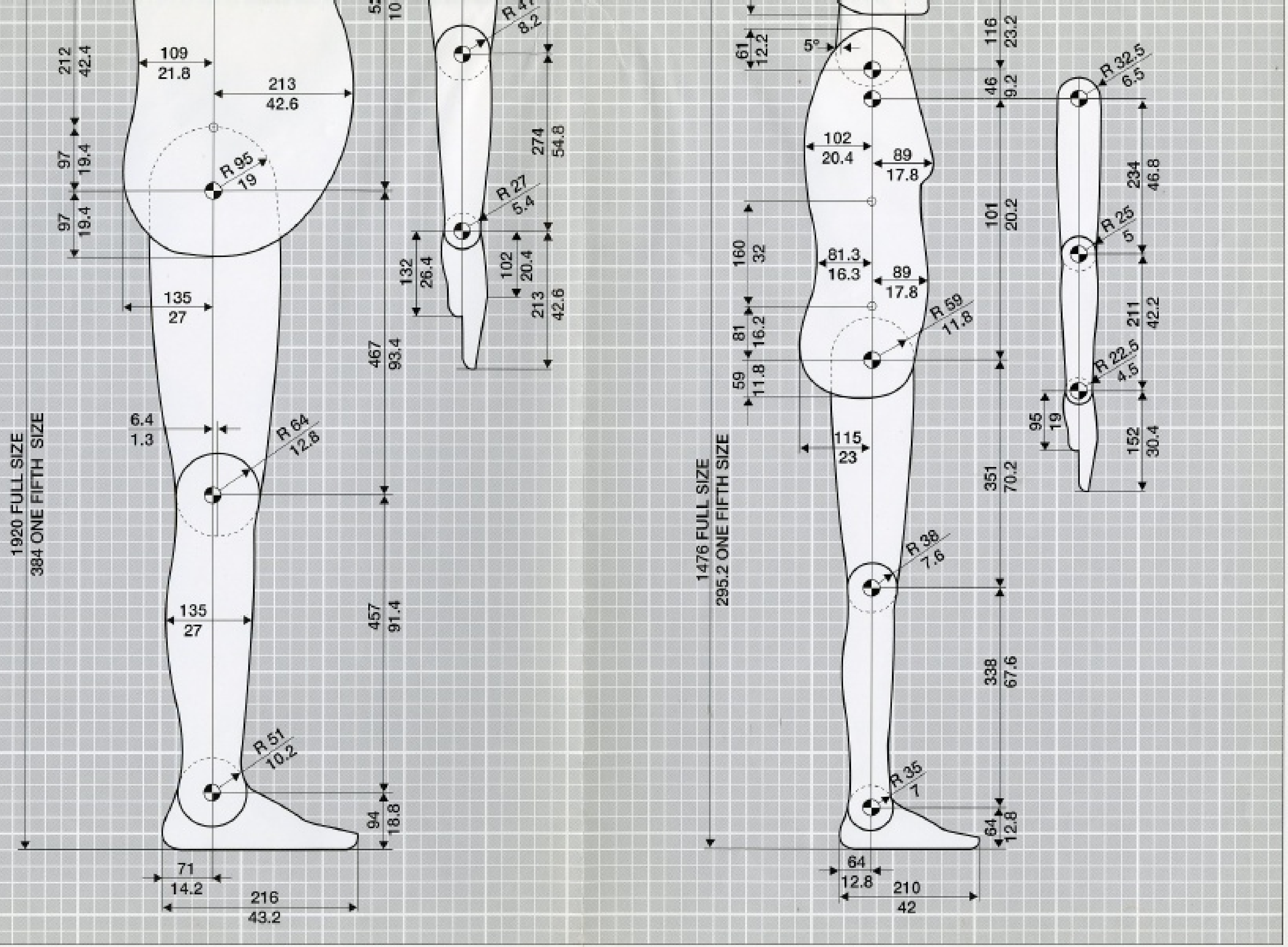
One Fifth Size Templates for 99 Percentile Man and Woman (in Millimeters)

Recommended template material: .031-.062" (1-3 mm) clear plastic.

- Eye hole. Recommended size: .140" (3mm) diameter.
- Two holes for affixing template to work surface. Insert pins through holes to hold template in place and allow for easy manipulation. Recommended diameter: .62" (1.5mm).
- Pivoting joint. Use grommets such as shoe eyelets to anchor pivot locations.
- Center rule. Scribe on body and arm and use as vertical reference to align the various body parts.



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