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ABSTRACT
        The paper describes the development of a computer
table for physically handicapped students including persons with
moderate to severe cerebral palsy, muscular dystrophy, uncontrolled
epilepsy, and paralysis due to physical trauma. The project first
reviewed furniture currently available for the physically handicapped
and then conducted ergonomic research concerning the design of a
computer table for the target population. Also considered were the
types of wheel chairs (Amigo, manual driven, electric motor driven)
and the physical characteristics of each chair in terms of door
clearance, wheel height, arm rest clearance, etc. A pilot study was
conducted during a summer school computer literacy class for the
physically handicapped to determine the physical access problems
encountered by the students and teachers. The final design of the
table incorporated the previous research. The paper includes shop
drawings, specifications, and design criteria at each decision point.
The resulting design is defended in light of the systematically
identified criteria. Appendixes provide data on tools needed for
production, wood materials needed, hardware needed, and costs of
hardware and materials (total cost $289.74). (Author/DB)

THE DESIGN
OF A COMPUTER TABLE
FOR THE PHYSICALLY
HANDICAPPED STUDENT
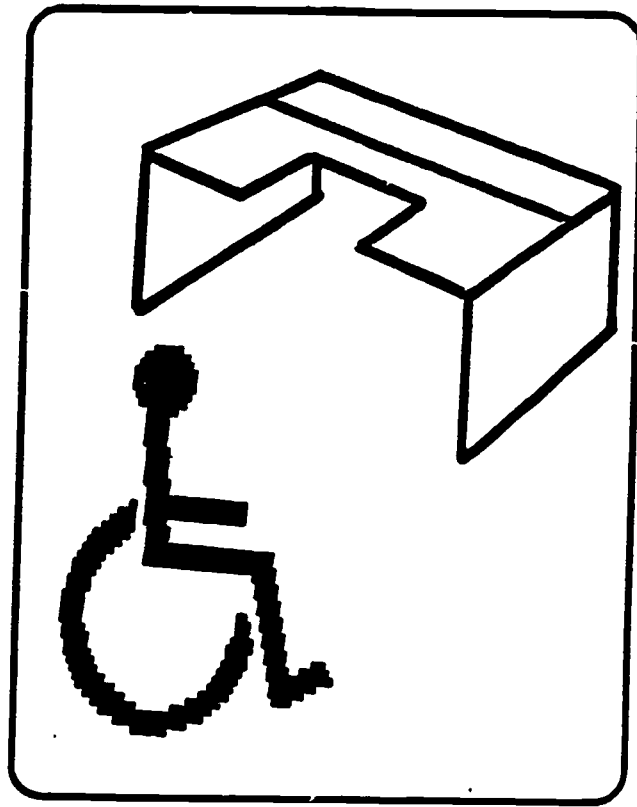
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Paper presented at the Annual Convention of the
Council for Exceptional Children
(66th, Washington, DC, March 28-April 1, 1988)

Important Note: To retain the original integrity of the
computer table table design the materials,
measurements, and assembly procedure <u>must</u>
be strickly followed.

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TABLE OF CONTENTS
CONTINUED

TABLE OF CONTENTS

iv

LIST OF TABLES

LIST OF FIGURES

8

A COMPUTER TABLE FOR THE PHYSICALLY HANDICAPPED

by

Lawrence Jeffrey Fitterman

An Abstract

viii

This project has as its target population the physically handicapped with special emphasis on the non-ambulatory. The population consists of those individuals with moderate to severe cerebral palsy, muscular dystrophy, uncontrolled epilepsy, and paralysis due to physical trauma. The project's purpose is to design a computer table for the defined target population. At the current time, the physically handicapped experience much difficulty in using existing furniture. The design enhances the target population use of computers to extend their abilities. A review of the literature featuring furniture for the physically handicapped has not revealed a computer table specifically designed for the defined target population. The project first addresses furniture currently available for the physically handicapped and then addresses the ergonomic research concerning the design of a computer table for the target population. Next, the project addresses the types of wheel chairs (Amigo, manual driven, electric motor driven operation) and the physical characteristics of each chair in terms of door clearance, wheel height, arm rest clearance, etc. Through observation and interview, a pilot study was conducted during a summer school computer literacy class for the physically handicapped at a local high school to study the physical access problems encountered by the students and teachers.

ix

Lastly, the project develops the design for the computer
table incorporating aforementioned research. Shop drawings
are developed so that the structural integrity and ergonomic
factors of the completed design can be evaluated. Criteria
for the design is clarified at each decision point and the
resulting product is defended in light of the systematically
identified criteria.

Abstract approved: _____
                    Major Professor: Dr. Gary Tubb

                    3/12/86
                    _____
                    Date of Approval

x

CHAPTER ONE
INTRODUCTION

According to The 1983, President's Committee on Employment of the Handicapped, an estimated one out of ten persons in the United States has limited mobility due to a temporary or a permanent physical handicap. These individuals are either ambulatory--physically mobile but with some physical limitations--or non-ambulatory--relying on some other means for mobility. This project is designed to aide the non-ambulatory segment of the overall target population, known as the physically handicapped, in the use of computers.

At this time, the furniture for these individuals is in the form of desks, tables, and other household furniture and fixtures that are designed for the non-handicapped and then modified for use by the physically handicapped..

PURPOSE

A rapidly increasing awareness of the enhanced potential
offered handicapped persons through the use of micro and
mini-computers has indicated the need for the development of
a unique computer table designed to accommodate the special
requirements of this target group. Some special
needs are: 1) higher and wider table clearances for the
whee. chair user, 2) restraints for stabilizing the unwanted
body movements of the user, and 3) sturdier construction.
Through the use of such a table design, more handicapped
individuals will be able to access a computer to enhance and
extend their abilities that otherwise would go untapped.
The purpose of the project is to design a computer table for
the target group and to test the design for strength and
stability. The project clearly documents the systematic
process of designing a computer table. Criteria for the
design is clarified at each decision point and the resulting
product is defended in light of the systematically
identified criteria.

DEFINITIONS AND DELIMITATIONS

The following are definitions that are unique to this project.

1. Frontal table access is defined as area needed for the individual and his or her wheel chair to fit comfortably up to and under the table.

2. Restraints are defined as those straps and/or braces (foam rubber, metal, plastic) needed to control unwanted movements in the arms, forearms and hands.

3. Wheel locking devices are defined as those mechanisms used to stop any unnecessary forward, backward or lateral movements of the wheelchair.

4. Peripheral access is defined as the amount of area around the desk needed for docking by an individual in a wheel chair.

5. Ergonomics is defined as "developing systems with the dimensions which can be adapted to the variety of people expected to use them" (Yeaman, 1983).

The following are delimitations that are unique to this
project. The computer table:

1. is not to be permanently connected to any permanent
    structure such as walls or floors.
2. does not have any electrical outlets or wires connected
    to the table.
3. tops do not tilt and remain parallel to the floor at all
    times.
4. does not have any wheels connected to the table legs.
5. is designed for computers with detachable keyboards.

CHAPTER TWO
DESIGN CONSIDERATIONS

Designing a computer table for the physically handicapped
individual requires precise planning and the ability to
devise individual solutions for specific limitations. The
designer should carefully consider the extent of the
individual's disability.

To assume that the disability involves solely an impairment
of the lower body can be a costly design mistake. As
Saltman and Chasin (1994) point out, such factors as the
strength and efficiency of one's grasp, the length of one's
arm reach, and the direction and degree one's upper body can
be bent should be determined before designing furniture.
Alfred Jacobson, vice president of Rehab Associates - a
consulting firm that designs and constructs housing
specially for the handicapped - suggests that an important
aspect in design approach "is the attention paid to the
individual's needs and capabilities of the clients and their
specific impairments." Jacobson's plans are devised after
consulting with rehabilitation nurses, physical therapists,
and occupational therapists. He emphasizes that "the best
assistant a designer can have is the person for whom the
work is intended. You have to get that person to function at
the highest level of their capability. Every situation is

different and they're all learning experiences."

An important affective element to strive to incorporate into a design for the physically handicapped is that the design should be considered by the user as an immediate part of his or her environment. Thus, a successful computer table design will first meet specifications to accommodate many types of wheel chairs and their users and, secondly, include an innovative but simple design for physical adjustments to adapt to each individual handicapped user.

Many ergonomic factors should be addressed when designing computer tables for wheel chair access. Wheel chairs are prescribed for patients based upon ten main sections: caster diameter, chair size, frame type, special frame construction, arm style, drive, back style, heavy duty construction, foot and leg support, and wheel construction.

ERGONOMIC FACTORS

The following three sections are most important when designing computer tables for wheel chair access.

The first section is chair size. Chair size refers to the seat area. There are seven main chair sizes designed to accommodate the individual user. The chair sizes range from

an 18" width with a 16" depth for adults to a tiny tot size

designed with a 12" width with an 11 1/2" depth. Thus, the
width of the space between the computer table legs and the
depth of the user computer table area must be defined to
accommodate the above range of various wheelchair sizes.

The second section is frame type. There are three main
types consisting of amputee, outdoor, and indoor frame
styles. The amputee type has no leg frame. The outdoor
style has leg restraints that consist of either a horizontal
bar with a leg holding strap or a high-ground clearance leg
restraint, and is a smaller version of the indoor leg
restraint. The indoor frame consists of a bulky but sturdy
vertical hung leg restraint such as ones attached to the
wheel chairs used at hospital emergency rooms. Thus, the
computer table must allow for the maximum 40 inch depth of
the wheel chair with an indoor frame.

The third section is arm style. Arm rests range from armless
to wrap-around, including other features such as adjustable,
rotating, non-detachable, or detachable--as used on the
sports model. The computer table must allow for the maximum
30 inch wheel chair height measured from the top of the arm
rests to the floor.

Not only should the ergonomics of the general populace be
considered, but the aforementioned three sections should be

considered if the computer table is to accommodate the

target population in the use of microcomputers.

Consistent with the concept that the design will first

accommodate many types of wheel chairs as well as adapt to

specific requirements, as mentioned above, the following

wheel chair measurements are a composite of maximum

dimensions recorded from each type of wheel chair used

during the pilot study:

- a maximum height of 30 inches measured from the floor
  to the top of the arm rests;
- a maximum width of 20 inches measured from the outside
  of the arm rests (Amigo chair) or a total maximum width
  of 27 inches (wheel chairs with horizontal propulsion
  levers on the hand wheels);
- a maximum length of 50 inches measured from the back of
  the wheels to the front leg rests, including an overlap
  for the feet and toes, and a maximum of 40 inches
  measured from the leg rests to the back rest of the
  seat.

Another important consideration when designing for this

segment of the population is the physical placement of the

designed furniture in the work room. The designed furniture

will be totally useless if the designer does not take into

account the minimum clearances needed by the target

population to gain access to the furniture within the work

room. The physically handicapped individual, in a
wheelchair (non-ambulatory), needs certain minimum
clearances to use each piece of furniture.

The method used by individuals to access and dock with the
computer table (peripheral access) involves the following
steps: 1) approach parallel to either side of the table
requiring a minimum clearance of 27 inches; 2) pass the
table by one full length of the wheelchair requiring a
minimum clearance of 50 inches; 3) make a slow turn around
until the front of the wheel chair is perpendicular with the
entrance site of the table; 4) move the chair to the table
until in a comfortable position; 5) lock the wheels using
the manual locks or by turning off the electric motor of the
wheelchair (See FIGURE 1). With respect to a table design,
radial measurement for access should be considered. The
minimum turning area required is a radius of approximately
50 inches. This radius is measured as the maximum length of
the wheel chair from the back of the wheels to the toes
and/or leg rests of the individual's wheelchair.

Step 1

Step 2

Step 3

Step 4
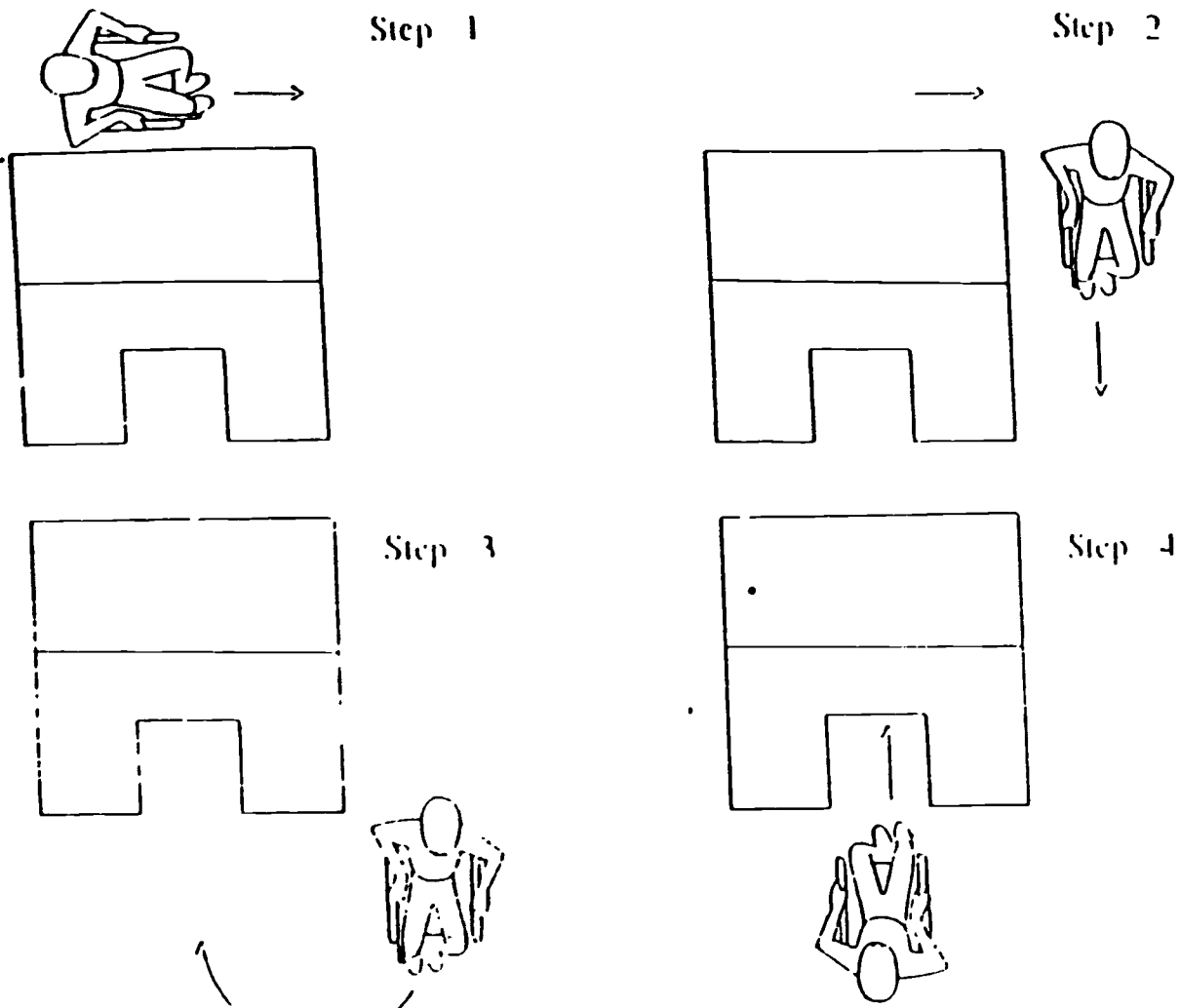
FIGURE 1 - FRONTAL TABLE ACCESS

21

CHAPTER THREE
PROCEDURE

The following text details the procedure for designing a
computer table for the physically handicapped. First, a
pilot study was conducted to gain valuable data through
direct observations of physically handicapped individuals to
conclude on what types of wheelchairs were used, minimal
clearances needed and the ways these students accessed
existing furniture. The pilot population consisted of
eight high school students, varying in age from thirteen to
sixteen years of age, confined to wheelchairs. The
students' mental capabilities ranged from an IQ of 62 to an
IQ greater than 136. Their physical disabilities included
physical trauma due to automobile accidents, moderate to
very severe cases of cerebral palsy, and moderate cases of
muscular dystrophy and spina biffida. Of the above
population, three students each had full use of their arms
and hands, two students each had moderate use of one arm and
hand with little or no use of the other arm and hand, and
three students each had no usable limb coordination
(forearms were in restraints). The last group used either a
marker-like object placed between their teeth or a head band
with a connected pointer for use as an input device. Five

students used the conventional indoor type wheelchairs, two

students used sport type wheelchairs and one student used an

Amigo wheelchair (electric cart with a conventional seat).

Secondly, the data from the pilot study, as detailed in

chapter two, was incorporated into the design.

The design procedure is divided into four sections. The

first section includes the development of a rough design

drawing based upon the pilot study and ergonomics.

Secondly, the rough design was tested through the use of a

structural design program (STRUDL - Structural Design

Language) using an IBM PC/AT. This program simulated a

physical test of the table's strength and stability under

work loads. Thirdly, a re-evaluation of the design was

conducted to reflect the synthesis of the program's test

findings. Lastly, final shop drawings were developed,

leading to the production of the actual computer table. The

shop drawings include a list of materials, tools needed for

production, production time projection and the estimated

cost of production.

CHAPTER FOUR
ROUGH DESIGN

The rough design procedure is divided into four sections.
The first section details the development of the computer
table tops. The second section details the development of
the computer table legs. The third section details the
development of the computer table top adjustment scheme.
The last section includes hardware and hardware positioning
for table assembly.

COMPUTER/USER TABLE TOPS

The computer table is designed with two separate tops to
ergonomically accommodate the need for adjusting the height
of the work area independently from the need for adjusting
the height of the video display. Each table top has rounded
corners, and flat surfaces that will not tilt to prevent
accidents that could otherwise be caused by collision with
sharp corners and heavy objects sliding off the table tops
onto the user.

The smaller back table top, termed the computer table top,
supports the computer; and the larger frontal table top,
termed the user table top, supports the computer keyboard
and serves as the user's work area.

The exterior corners and interior angles of the table are rounded to reduce any chance of a physical injury to the user.

Both computer table tops are composed of 1 inch solid wood. Solid wood is recommended because of its strength and endurance (Ramsey & Sleeper, 1970).

USER TABLE TOP
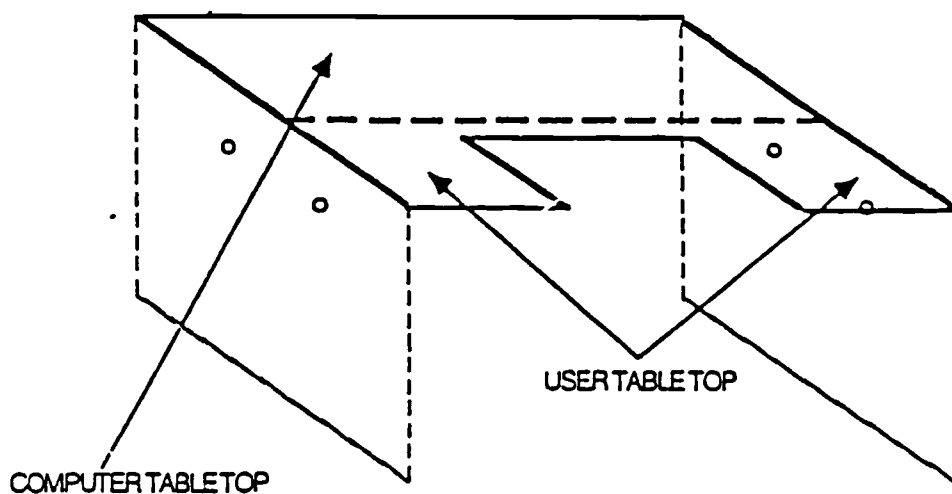
COMPUTER TABLE TOP

FIGURE 2 - THREE-QUARTER VIEW OF COMPUTER TABLE TOPS

COMPUTER TABLE TOP

The computer table top is designed to accommodate the
maximum depth, width and length of microcomputers with
detachable keyboards (See Table 1). The data derived from
Table 1 concludes that the minimum and maximum depths of
8.00 to 16.00 inches are needed to accommodate all current
microcomputers. The minimum and maximum widths and heights
do not prove to be critical in the design because of the 48
inch width and the computer work area's height
adjustability.

TABLE 1
MEASUREMENTS OF COMPUTERS WITH DETACHABLE KEYBOARDS

COMPUTER	DEPTH	WIDTH	HEIGHT
IBM PC/XT	16.00 inches	19.00 inches	5.50 inches
IBM PCjr	11.00 inches	13.75 inches	4.00 inches
TANDY 1000	13.25 inches	16.00 inches	5.75 inches
COMMODORE 64	8.00 inches	16.00 inches	2.25 inches
APPLE-MACINTOSH	12.00 inches	9.50 inches	16.00 inches

The depth of the table top not only accommodates the
computer but allows a range for viewing the monitor from a
minimum depth of 10.50 inches to a maximum of 16.50 inches
(See Table 2). The data derived from Table 2 concludes that

the minimum and maximum depths of 12.00 and 15.50 inches
for computer monitors fit within the tolerance range of the
computer area of 10.50 to 16.50 inches.

The minimum tolerance range is figured by adding the 10
inches of the computer work area that houses the keyboard to
the .50 inch of the space between the tables. The maximum
tolerance range is figured by subtracting the minimum depth
of a computer monitor (12.00 inches) from the 18.00
inch depth of the computer table top (See Figure 7).

TABLE 2
MEASUREMENTS OF COMPUTER MONITORS

MONITOR	DEPTH	WIDTH
IBM PC/XT (RGB)	15.00 inches	15.00 inches
IBM PCjr (RGB)	15.00 inches	14.00 inches
IBM PC/XT (MONOCHROME)	12.00 inches	14.75 inches
TANDY CM-2 (RGB)	13.25 inches	16.00 inches
COMMODORE 1702 (COMPOSITE)	15.50 inches	14.50 inches
APPLE/MACINTOSH	12.00 inches	9.50 inches
AMDEK COLOR I (COMPOSITE)	16.00 inches	15.00 inches

USER TABLE TOP

The user table top measures 24 inches in depth by 48 inches in width. One of the main premises in the design of this computer table is that the user should feel as if he/she is part of his/her immediate environment. With this premise in mind, a cut-a-way is designed into the user work area. This cut-a-way area, in which the user docks, measures 16.50 inches in width by 14 inches in depth.

To determine the dimensions of the cut-a-way area, individuals, ranging in age from 11 to 37 years old and randomly selected from a junior and senior high school and a college, were measured for torso width and the results compiled in Table 3. The data in Table 3 concludes that the minimum and maximum torso widths, measured at the bottom of the rib cage, are 8.50 and 14.00 inches. The 16.50 inch width of the cut-a-way area accommodates a maximum torso width of over 16 inches which is well within the average torso width of 10 to 15 inches. The 14 inch depth of the cut-a-way accommodates any user including a user with a torso brace (See Table 3).

TABLE 3
MEASUREMENTS OF TORSO WIDTH IN INCHES

GENDER	AGE	WIDTH	WAIST
F	11	9.50	27.00
F*	16	14.00	39.50
F	17	10.00	28.00
F	21	9.00	27.00
F	27	8.50	24.00
F	32	11.00	30.00
F	33	10.00	29.00
	==	=====	=====
AVERAGE	22	10.29	29.21

* denotes individual with torso brace

GRAPH OF TABLE 3

■ FEMALE TORSO WIDTH

2∂
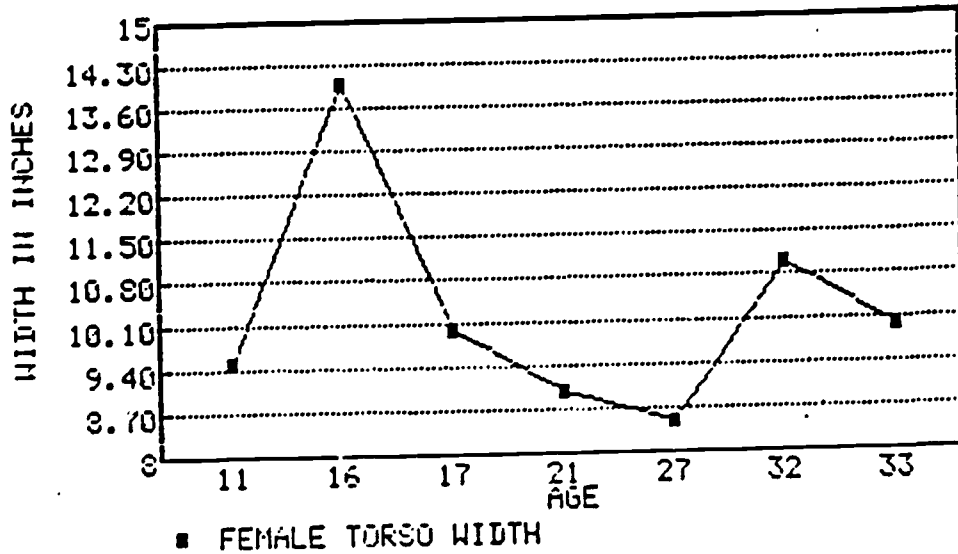
TABLE 3
MEASUREMENTS OF TORSO WIDTH IN INCHES

GENDER	AGE	WIDTH	WAIST
M	12	8.50	22.00
M	15	12.50	34.00
M*	17	11.50	34.00
M	19	11.00	27.00
M	20	9.00	26.00
M	32	12.50	34.00
M	37	12.00	34.00
AVERAGE	22	11.00	30.14

* denotes individual with torso brace

GRAPH OF TABLE 3

◆ MALE TORSO WIDTH
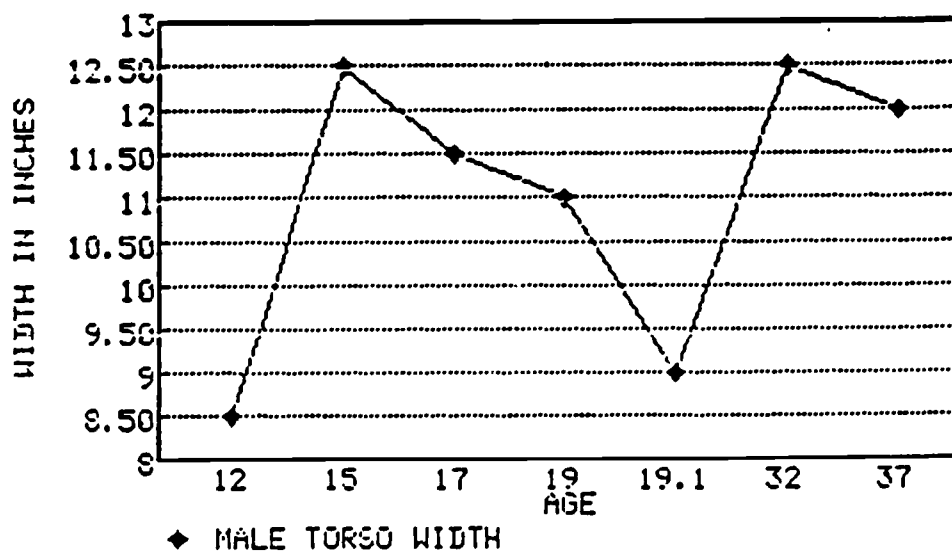
A rectangular work area of 15.75 inches by 24 inches remains on either side of the cut-a-way. The remaining 10 inch area in front of the cut-a-way accomodates the computer keyboard (See Table 4). The data derived from Table 4 concludes that the minimum and maximum clearances needed to accommodate the keyboard are 5.75 and 8.00 inches. This clearance is well within the 10 inch tolerance range.

TABLE 4
MEASUREMENTS OF DETACHABLE KEYBOARDS

KEYBOARD	DEPTH	WIDTH
IBM PC/XT	7.50 inches	19.00 inches
IBM PCjr	6.50 inches	13.50 inches
TANDY 1000	7.75 inches	16.00 inches
COMMODORE 64	8.00 inches	16.00 inches
APPLE-MACINTOSH	5.75 inches	13.25 inches

COMPUTER TABLE SUPPORT LEGS

The computer table tops are supported by two main 1 inch thick solid wood rectangular support legs measuring 26 inches in height by 40 inches in width (See Figure 9). The height of the support leg accommodates the minimum clearance of 24 inches needed by any type of wheelchair. The width of

the support leg is computed by adding the depth of the
table tops, plus the .50 inch space between the table tops,
then subtracting a 1.25 inch overhang across the front and
back of the computer table tops (Ramsey & Sleeper, 1970).
Along bottom of each support leg two 1 inch by 2 inch by 40
inch runners that are connected to give added lateral and
vertical support (See Figure 10). Recessing the support legs
increases the ability to handle and adjust the table tops.
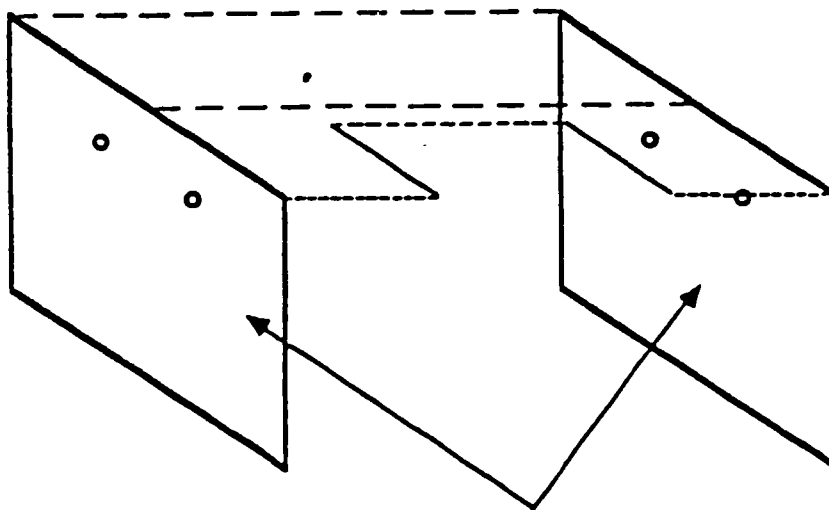
COMPUTER TABLE SUPPORT LEGS

FIGURE 3 - THREE-QUARTER VIEW OF COMPUTER SUPPORT LEGS

increases the ability to handle and adjust the table tops.

TABLE TOP ADJUSTMENT SCHEMES

The adjustment scheme is divided into the adjustable table
top supports for both table tops and the placement and
design of the adjustment holes.

USER TABLE TOP SUPPORT

This adjustable support is designed to support the user work
area table top, to connect the table top to the computer
table legs, and to adjust the height of the table top. The
support measures 22 inches in width by 13 inches in height
by 1 inch thickness (See Figure 9 & 10). The adjustable
support has two 1 inch by 1 inch by 22 inch stops that run
the width of the support (See Figure 9). These stops
connect to the table top and the adjustable support. The

stops are also added to the design to both increase the
stability of the table top and to act as a physical stop in
case the table is inadvertently dropped onto the computer
legs. Otherwise, if the table top is dropped, the
possibility of weakening the connection between the table
top and the support and thus the stability of the table can

occur. At rest, the user work area table top surface is two
inches above the computer legs, 26 inches above the floor
and has a user clearance of 25 inches from the floor to the
bottom of the user work area table top.

USER TABLE TOP ADJUSTMENT SCHEME

The user work area table top is designed to adjust at
increments of 2 inches. The 3/8 inch holes are drilled
through the table top support, beginning at 3 inches below
the bottom of the table top and then every 2 inches to a
depth of 11 inches (See Figure 9 & 10). Drilling more holes
at less of an increment would weaken the integrity of the
the table top supports (Ramsey & Sleeper, 1970). This
arrangement allows the user table top to adjust from a
minimum height of 26 inches to a maximum height of 34 inches
above the floor, based upon minimum and maximum wheelchair
clearances (See Page 8).

COMPUTER TABLE TOP SUPPORT

The adjustable computer table top support is designed to
support the computer table top, connect the table top to the
computer table legs, and adjust the height of the table
top. The support measures 16 inches in width by 16 inches
in height by 1 inch thickness (See Figure 9 & 10). The

adjustable support has two 1 inch by 1 inch by 16 inch stops

that run the width of the support. These stops are designed

to connect to the table top and the adjustable support. The

stops are also added to the design both to increase the

stability and to act as a physical stop in case the table is

inadvertently dropped onto the computer legs. At rest, the

computer table top is two inches above the computer legs, 26

inches above the floor, and has a user clearance of 25

inches between the floor and the bottom of the table top.

COMPUTER TABLE TOP ADJUSTMENT SCHEME

The computer table top is designed to adjust at variable

increments of 2, 3, 2, 2, and 3 inches. The 3/8 inch holes

are drilled beginning 3 inches below the bottom of the table

top and then 3, 2, 2, and 3 inches to a depth of 13 inches

(See Figure 9 & 10). Drilling more holes at less of an

increment would weaken the integrity of the the table top

supports (Ramsey & Sleeper, 1970). This allows the computer

table top area to adjust from a minimum height of 26 inches

to a maximum height of 39 inches above the floor, based upon

minimum and maximum wheelchair clearances (See Page 8).

DESIGN SUPPORT OF ADJUSTMENT SCHEME

The design scheme is based on the sound ergonomic research that the center of the computer's video display should be 3 inches above the keyboard (M. Helander, 1982). In support of the aforementioned research, the computer table top assembly, which consists of the support and the computer table top, should be adjusted to the second adjustment hole and the user work area table top assembly should be at rest in the first hole (See Figure 9). If the user work area assembly is raised to the next level, the computer table top assembly can be raised to its next corresponding hole to maintain the 3 inch differential. Users must also take into consideration the monitor and computer unit's height when at rest on the computer table.

HARDWARE AND ASSEMBLY

The computer table is assembled in four phases. The first phase involves the assembly of the runners to the table support legs and the table top supports. The second phase involves the attachment of the table top supports to the table tops. The third phase involves the attachment of the table top support assembly to the table support legs. The

last phase involves the attachment of the back support to the computer table assembly (See Appendix 1-5).

In the first phase, the runners to the table support legs and the table top supports are connected by wood glue (aliphatic resin; a strong, fast setting, heat and water resistant glue for working with wood); and held in place by adjustable wood clamps for a period of 30 minutes (See Appendix 1). Additional, 1 1/4 inch finishing nails will be driven every 4 inches to insure that there is no later separation (See Appendix 3). In the second phase, the table top supports are connected to the table tops by 2 inch long by 1/4 inch in diameter flat head screws (See Appendix 3). The pilot holes for these screws are counter sunk to avoid exposed surface metal. The pilot holes on the computer table top are placed every 4 inches as shown in Figure 7. The pilot holes on the user table top are be placed every 5 1/2 inches as shown in Figure 7.

In the third phase, the table support legs, one at a time, are rested on their back edges (See Figure 9) and held in a vertical position. The table top assemblies are then attached to the first table support leg with the use of a 2 1/2 inch long by 3/8 inch in diameter stove bolt (See Appendix 3). The head of the stove bolt faces toward the outside of the table and is flush with the surface of the computer table legs. Recessing the head of the

stove bolt into the wood only succeeds in weakening the structural integrity of the computer table legs. The computer support leg and table top assembly are assembled through the existing holes as shown in Figure 10. The two pieces are held in place by a 3/8 inch flat and lock washer and a 3/8 inch hexagon nut (See Appendix 3). The table top assemblies are attached to the second table support leg in the same manner.

In the last phase, the 44 by 22 by 3/8 inch back brace is attached to the back of the table support legs with the use of 2 inch long by 1/4 inch in diameter flat head screws (Appendix 2-3). The pilot holes for these screws are counter sunk so that there is no exposed surface metal and needless obstacles that can produce potential hazards and inconveniences. Examples of such hazards and inconveniences are scratches to the user's body from exposed metal and the inability to lay books and papers flat on the table tops. The pilot holes are drilled starting 3 inches from the top of the back brace and then every 4 inches as shown in Figure 7.

The complete computer table has no reinforcing cross-bars to interfere with the docking of the user to this computer table. The computer table may be sanded, stained and painted with polyurethane to give a smooth exterior surface.

CHAPTER FIVE
STRUCTURAL ANALYSIS

The structural analysis of the computer table is divided into three structural tests. The first analysis tests the structural concept of tipping. The second tests the structural concept of hinged collapse. The last analysis tests the concept of flexural stress from various loads.

Tipping Analysis

1. Tipping is a structural phenomena that can occur for this table when the table top is struck with a horizontal force at the operator opening. The following five assumptions are made concerning this table and the phenomenon of tipping:

   1. Dead load (weight of hardware and table)
      Hardware = 30 lbs.

   2. Back of table is secured at the floor to prevent sliding.

   3. Centroid (center of gravity) of the table is centered in all three dimensions.

   4. Average height (due to adjustable top) is 30 inches.

   5. The unit of weight for red oak wood is 47 lbs./cu.ft.

The volume of the wood is necessary to find the total weight of the table alone. The total weight of the table is figured by multiplying the sum total volume of all wood table parts in cubic feet (3.50 cu.ft.) by the weight (lbs.) of the wood per cubic foot (47 lbs./cu.ft.).

TABLE 5
THE TOTAL WEIGHT OF THE WOOD

1. Computer top: 18" X 48" X 1" = 0.50 cu.ft.

2. Desk top:

    (24" X 48" x 1") - (16 1/2" X 14" X 1") = 0.53 cu.ft

3. Back: 22" X 44" X 1" = 0.56 cu.ft.

4. Slides (2):   (22" X 40" X 1")2 = 1.02 cu.ft.

5. Computer top legs (2):   (16" X 15" X 1")2 = 0.28 cu.ft.

6. Desk top legs (2):   (22" X 13" X 1")2 = 0.33 cu.ft.

7. Computer top stops (4):   (1" X 1" X 16")4 = 0.04 cu.ft.

8. Desk top stops (4):   (1" X 1" X 22")4 = 0.05 cu.ft.

9. Floor braces (4):   (1" X 2" X 40")4 = 0.19 cu.ft.
                            =================================
                    TOTAL VOLUME OF WOOD = 3.50 cu.ft.

                    TOTAL WEIGHT OF WOOD = 164.50 lbs.
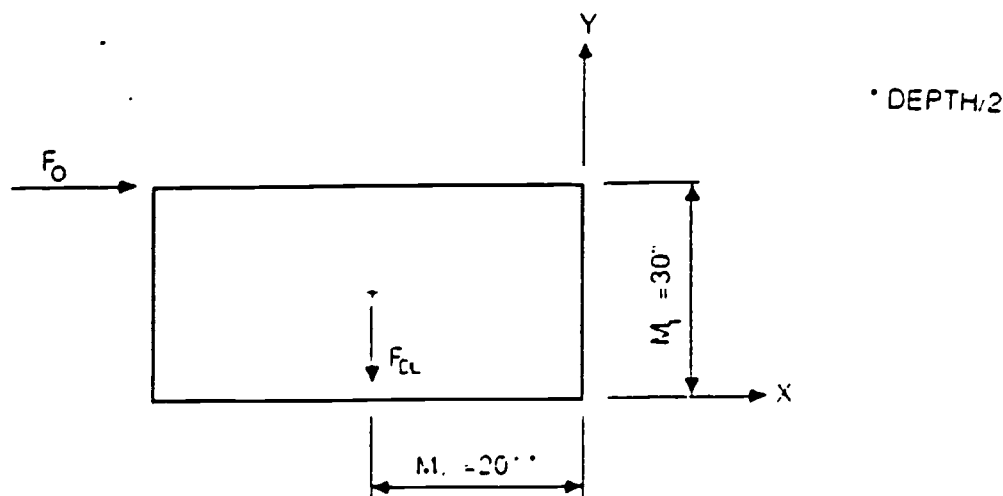
FIGURE 4 · FREE BODY DIAGRAM

F_O = Force against table by the operator

F_{DL} = Dead load weight (wt. of table and hardware)

M_1 = Average height

M_2 = Depth of the table divided by 2

Definition of the Moment of the Force- Tipping occurs when:

$$F_O(M_1) > F_{DL}(M_2)$$

$$F_O > \frac{F_{DL}(M_2)}{M_1}$$

$$F_{DL} = 3.50\ C.F.\ (47\ \#/C.F.) + 30\ LBS = 194.5\ IBS.$$

$$F_O > \frac{194.5\ \#\ (20")}{(30")} > 130\#$$

Therefore, as long as the user does not exert a horizontal force in excess of 130 lbs. against the table, under the aforementioned conditions, the table does not tip.

Hinged Collapse

Hinged collapse is a phenomenon common in a simple frame as shown below when a sideways force is exerted.
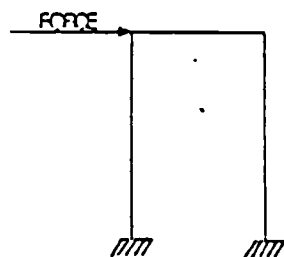
FIGURE 5A - HINGED COLLAPSE CONDITION
BEFORE FORCE APPLIED
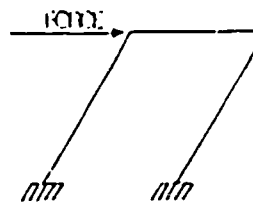
FIGURE 5B - HINGED COLLAPSE CONDITION
AFTER FORCE APPLIED

To prevent this, generally cross bracing is provided:
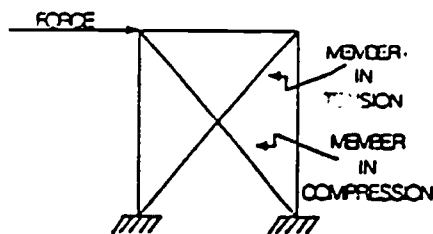
FIGURE 5C - GENERAL CROSS BRACING

As the solid members (top, sides and back) provide the same support as the typical cross bracing, the hinge failure cannot occur unless a force is exerted which either buckles the wood panels or the screwed connections fail. Due to the function or purpose of this table, this condition is highly improbable.

Load Analysis

Load analysis is the maximum flexural stress determined for
a worst case load on the desk top. The following four
assumptions are made concerning this table and the
phenomenon of load analysis:

1. Dead load -

    a) computer/keyboard - 30 lbs.

    b) monitor - 30 lbs.

    c) miscellaneous equipment - 25 lbs.

    d) manuals and books - 15 lbs.

Estimated maximum dead total load is 100 lbs.

Young's Modules of Elasticity:
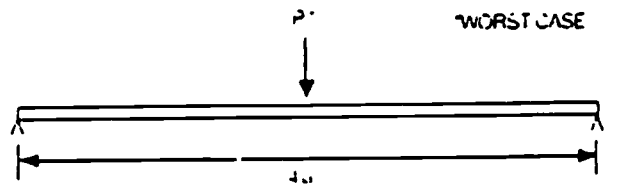
FIGURE 6 · FLEXURAL STRESS FOR WORST CASE

$I = 1.12 \, bh^2 = 1.12 \,(48")(1") = 4^{-4}$

Where $\bar{y}$ = the centroid axis

$M = Pad = 100ñ(24") = 1200 \, in \, lbs$

$\sum \frac{M\bar{y}}{I} = \frac{1200 \, in \, lbs (0.5")}{4^{-4}} = 150 \, psi$

Therefore, under the worst conditions, the table top
resists a bending of 150 psi. which is greater than the
estimated load.

Check for maximum load in the table supports for
buckling:

The effective slender ratio:

$$(kl/r)_0 = \dfrac{(1)30"}{\dfrac{16}{2\sqrt{3}}} = 6\,49$$

Where:

    $k = 1 \cdot$ pinned $\cdot$ pinned

    $r =$ radius of gyration

    $r = \sqrt{I/A}$

The least value of (kl/r) for which Euler's formula remains
valid is: assume proportional limit, 4.6×10^3 psi.
for red oak.

$$(kl/r)_0 = \sqrt{\dfrac{\pi^2 E}{\Sigma_{pl}}} = \sqrt{\dfrac{\pi^2 (1\,5 \times 10^6)}{4\,6 \times 10^3}} = 56.$$

For Euler's column formula to be valid:

$$\Sigma_{cr} > \Sigma_{pl} \longrightarrow (kl/r)_x > (kl/r)_0$$

Since this is not the case, the sides of the desk fall into
the category of short columns. Short columns have a high
tolerance for buckling (refer to section on Hinged
Collapse). The table top is be the controlling factor on
any failure due to loading.

RE-EVALUATION OF DESIGN

Through informal interviews with the target population and their educational counterparts; at an area high school, a major vocational education center, an area college, and an educationl conference, the concept of table restraints for restricting unwanted body movements was deleted from the design. The interviewed potential users see the concept of the table restraints as unwarranted for the following reasons:

1. upper limb restraints can be integrated with wheelchairs.

2. restraints are viewed as a personal affront to the users' dignity.

3. users can control their own movements.

4. users can rest their upper limbs on the user table top work areas limiting most of the unwanted movements.

5. physical limitations prohibit some users from placing their upper limbs on the table top to use the restaints.

The synthesis of the aforementioned structural testing has concluded that no design changes are necessary and that the design does not exhibit any safety hazards due to normal stress as concluded in the following data:

1. Tipping occurs only if a horizontal force of greater than 130 lbs. of force -is applied to the user's opening in the user desk top. If the table is pushed flush against the wall, tipping is improbable.

2. Hinged collapse is highly improbable because of the design incorporating a top, side and back. Also, it is very unlikely that the force needed to buckle the hinges is ever exerted under normal usage. Short column structures have a high tolerance for buckling.

3. Load analysis has demonstrated that a load of 150 psi. is needed to cause the table tops to flex (flexural stress) under a maximum load of 100 lbs. Therefore, under the worst conditions, the table top will resist a bending force of 150 psi. which is far greater than the estimated load. The table top is the controlling factor on any failure due to loading.

SELECTED REFERENCES

R. Garrison.   Special Needs Housing. Home and Design, July, 1984.

I. Granet.   Strength of Materials for Engineering Technology. Concepts of Stress and Strain, 1973.

M. Helander.   The Video Display Terminal Design Handbook. Canyon Research Group, Inc., June 1982.

R. Hibbeler. Engineering Mechanics:Statics. Macmillan Publishing Co., Inc., 1978.

J. Makower.   Office Furniture That Fits. Usair, 1983.

J. Panero and M. Zelnick.   Human Dimension and Interior Space: A Source Book of Design Reference Standards, 1979.

C. Ramsey and H. Sleeper.   Architectural Graphic Standards. General Planning and Design, 1970.

J. Saltman and J. Chasin.   The Wheelchair in The Kitchen. Cabinet Design, Mar. 1984.

A. Yeaman. Microcomputer Learning Stations and Student Health and Safety: Planning, Evaluation and Revision of Physical Arrangements. Educational Technology, Dec. 1983.

APPENDIXES

APPENDIX 1
TOOLS NEEDED FOR PRODUCTION.

1. Band saw - used for cutting curves

2. Radial arm or table saw - used for cutting straight
                              lines

3. Jointer / planer - used to level off the high spots on
                      the surface of the wood

4. Belt disk sander - used for smoothing exterior corners

5. Bench or floor type drill press - used for producing
                                     accurate holes

6. Wood bits/assorted - used to produce pilot holes for
                        wood screws and for adjustments
                        holes

7. Wood vise - used for holding wood for drilling and
               final finishing

8. Aajustable wrench - used to tighten nut of stove bolts

9. Phillips / regular blade screwdrivers - used to drive
                                           flat head wood
                                           screws

10. Hack saw / metal blade - used to cut off extra length of
                             stove bolts

11. Metal file - used to smooth the cut end of the stove
                 bolts

APPENDIX 2
WOOD MATERIALS NEEDED FOR PRODUCTION

Measurements	Size	Type	# of Pieces
160 inches/length .	1" x 2"	Red Oak	1
152 inches/length	1" x 1"	Red Oak	1
48 inches x 22 inches	3/8 "	Red Oak	1
40 inches x 24 inches	1"	Red Oak	2
16 inches x 16 inches	1"	Red Oak	2
22 inches x 13 inches	1"	Red Oak	2
24 inches x 48 inches	1"	Red Oak	1
18 inches x 48 inches	1"	Red Oak	1

* This is a total of 3.50 cu.ft. of red oak. ·

APPENDIX 3
HARDWARE NEEDED FOR PRODUCTION

Size	Description	Quantity
1 1/4 inch	finishing nails	50
2 inch x 1/2 inch	flat head wood screw	22
16 ounces	Aliphatic resin/glue	1
2 1/2 inch x 3/8 inch	stove bolt	2
3/8 inch	flat washer	2
3/8 inch	lock washer	2
3/8 inch	hexagon nut	2
Medium to extra fine	sandpaper	1 pkg
Triple 0	steel wool	1 pkg
1/2 gallon	polyurethane	1
1/2 gallon	stain (optional)	1

APPENDIX 4
ESTIMATED COST FOR PRODUCTION

Hardware - Description - Quantity	Cost
1 1/4 inch - finishing nails - 50 pieces	0.89
2 inch x 1/2 inch - flat head wood screw - 22 pieces	2.49
16 ounces - Aliphatic resin/glue - 1 container	4.29
2 1/2 inch x 3/8 inch - stove bolt - 2 pieces	0.98
3/8 inch - flat washer - 2 pieces	0.08
3/8 inch - lock washer - 2 pieces	0.09
3/8 inch - hexagon nut - 2 pieces	0.09
Medium to extra fine - sandpaper - 1 package	1.59
Triple 0 - steel wool - 1 package	1.99
1/2 gallon - polyurethane - 1 container	17.98
1/2 gallon - stain (optional) - 1 container	17.98

Sub Total of hardware costs - $ 48.45

APPENDIX 4
ESTIMATED COST FOR PRODUCTION

Wood - Description - Quantity	Cost
160 inches/length - 1" x 2" - Red Oak - 1 piece	11.93
152 inches/length - 1" x 1" - Red Oak - 1 piece	5.66
48 inches x 22 inches - 3/8 " - Red Oak - 1 piece	36.06
40 inches x 24 inches - 1" - Red Qak - 2 pieces	71.56
16 inches x 16 inches - 1" - Red Oak - 2 pieces	19.08
22 inches x 13 inches - 1" - Red Oak - 2·pieces	21.32
24 inches x 48 inches - 1" - Red Oak - 1 piece	42.93
18 inches x 48 inches - 1" - Red Oak - 1 piece	32.20

Sub Total of wood costs - $ 240.74

Total cost of materials - $ 289.74

APPENDIX 5
PRODUCTION TIME

The time necessary for production is decided on three factors. . The first factor is the availability of materials. The second factor is the availability of the correct tools needed for production. The last factor is the degree of skill and knowledge of the builder in the use of the tools and working with the medium of wood. Taking into account the aforementioned factors, it is estimated that a skilled builder can construct a finished product in 8 hours. . This estimation considers only the builder's time and not the time for finishing, staining, or allowing the glue to dry.

SHOP DRAWINGS

FIGURE 7 - TOP VIEW
1/8" = 1"

Back ⌐ (3/8" Thickness)

2"-1/4"⌀ Flat Hd Wood Screws

Side Leg & Brace (1" Thickness)
Adjustable Leg (1" Thickness)
Brace (1" Thickness)

⌐ Adjustable Computer Desk Top (1" Thickness) ⌐

18"

1/2"

2"

⌐ Adjustable Desk Top (1" Thickness) ⌐

20"

14'

10'

16'1/2"

48"

2"

5'1/2"

2'

2"-1/4"⌀ Flat Hd Wood Screws

(Side Leg Floor Braces Not Shown this View)

For Bolt Hole Details, See Fig. 9

48"

Adjustable Computer Desk Top
(1" Thickness)

1"x1" Adjustable Leg Braces (4 Sets)

Adjustable Desk Top
(1" Thickness)

Desk Top Adjustable Leg
(1" Thickness)

Computer Desk Top
Adjustable Leg
(1" Thickness)

Back
(3/8" Thickness)

Side Leg
(1" Thickness)

22"

1"x2" Side Leg
Floor Braces
(2 Sets)

44"
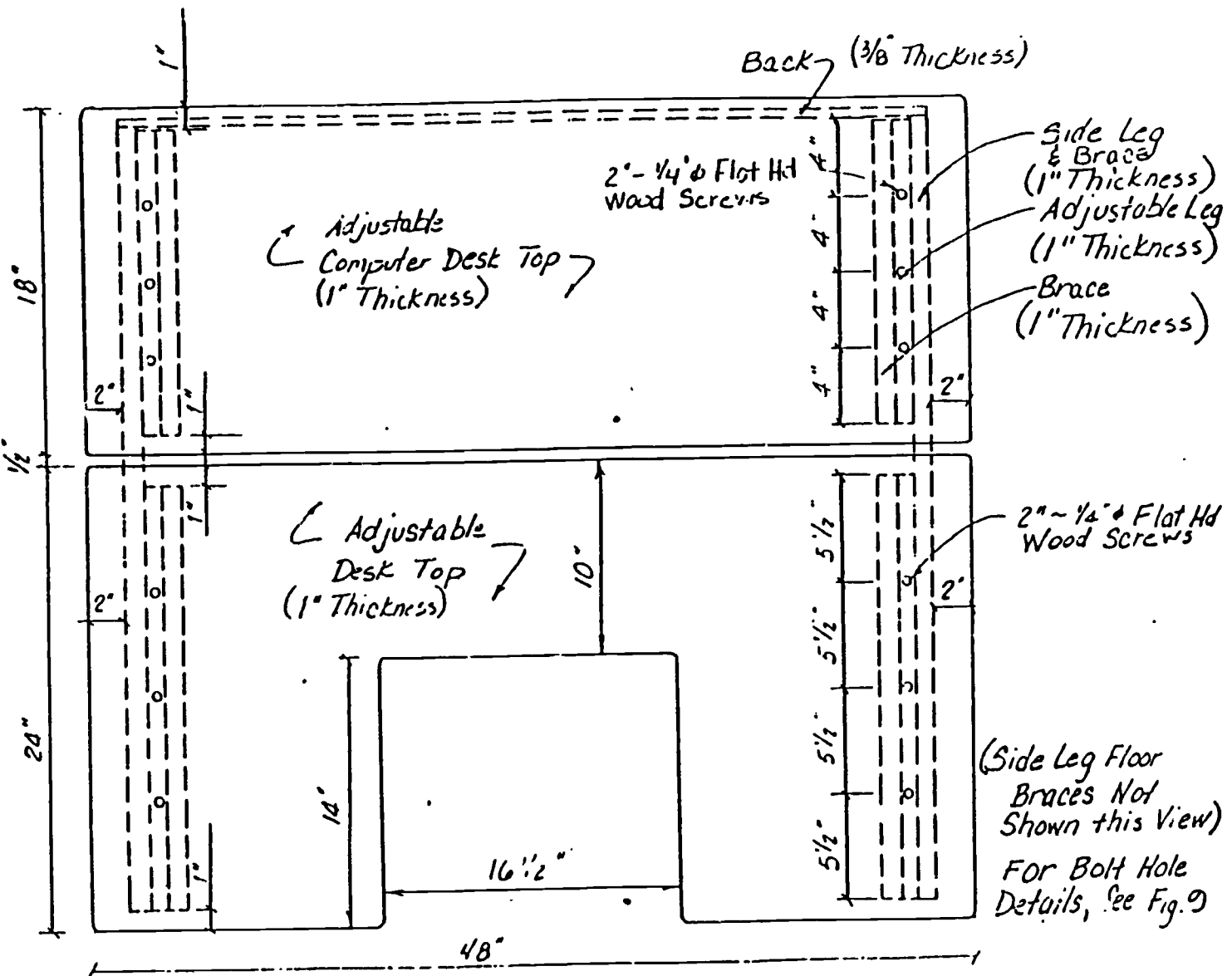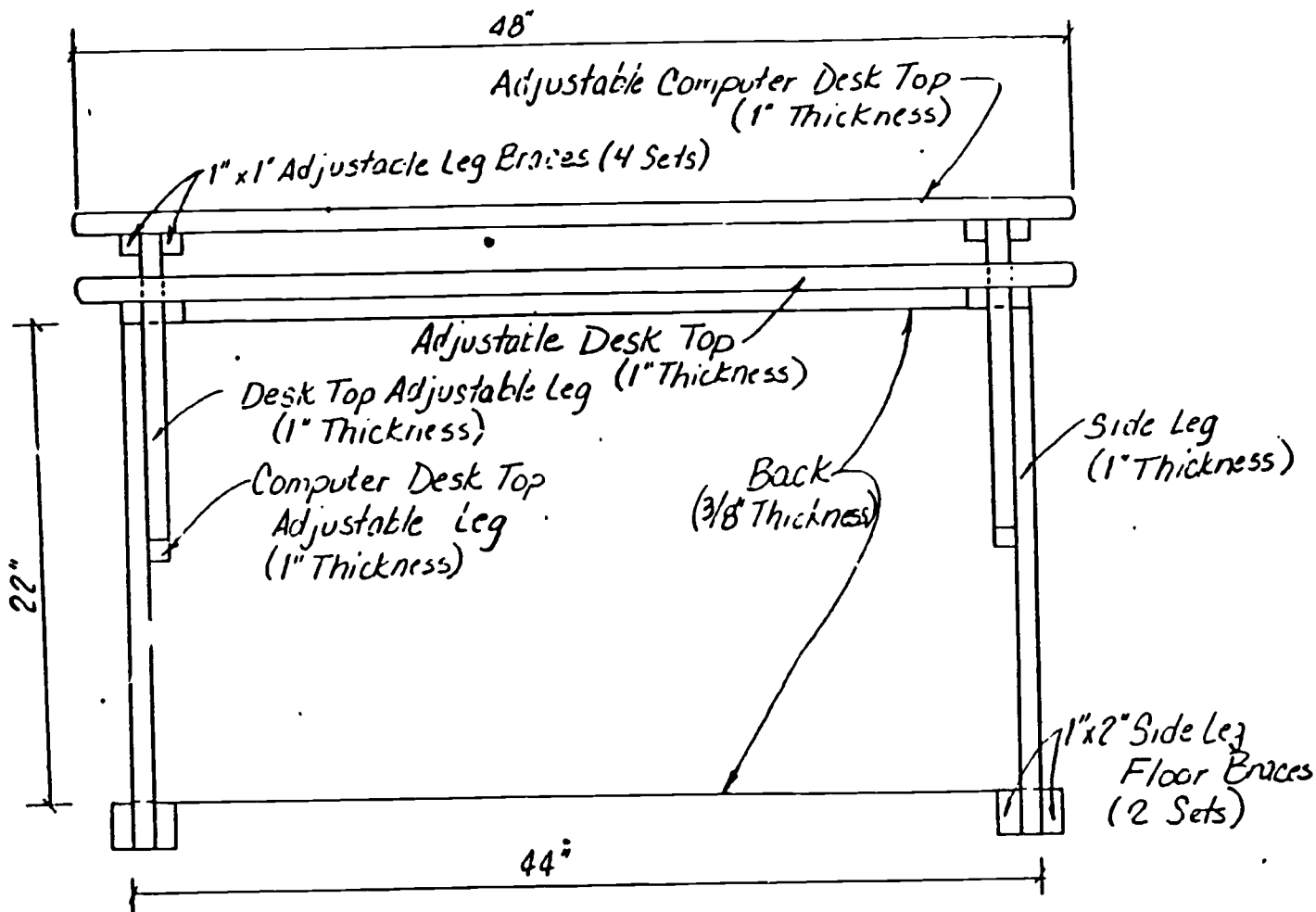
FIGURE 8
FRONT VIEW - 1/8" · 1"
(Shown Standard Position -- Computer Desk Top 3" Above Desk Top)
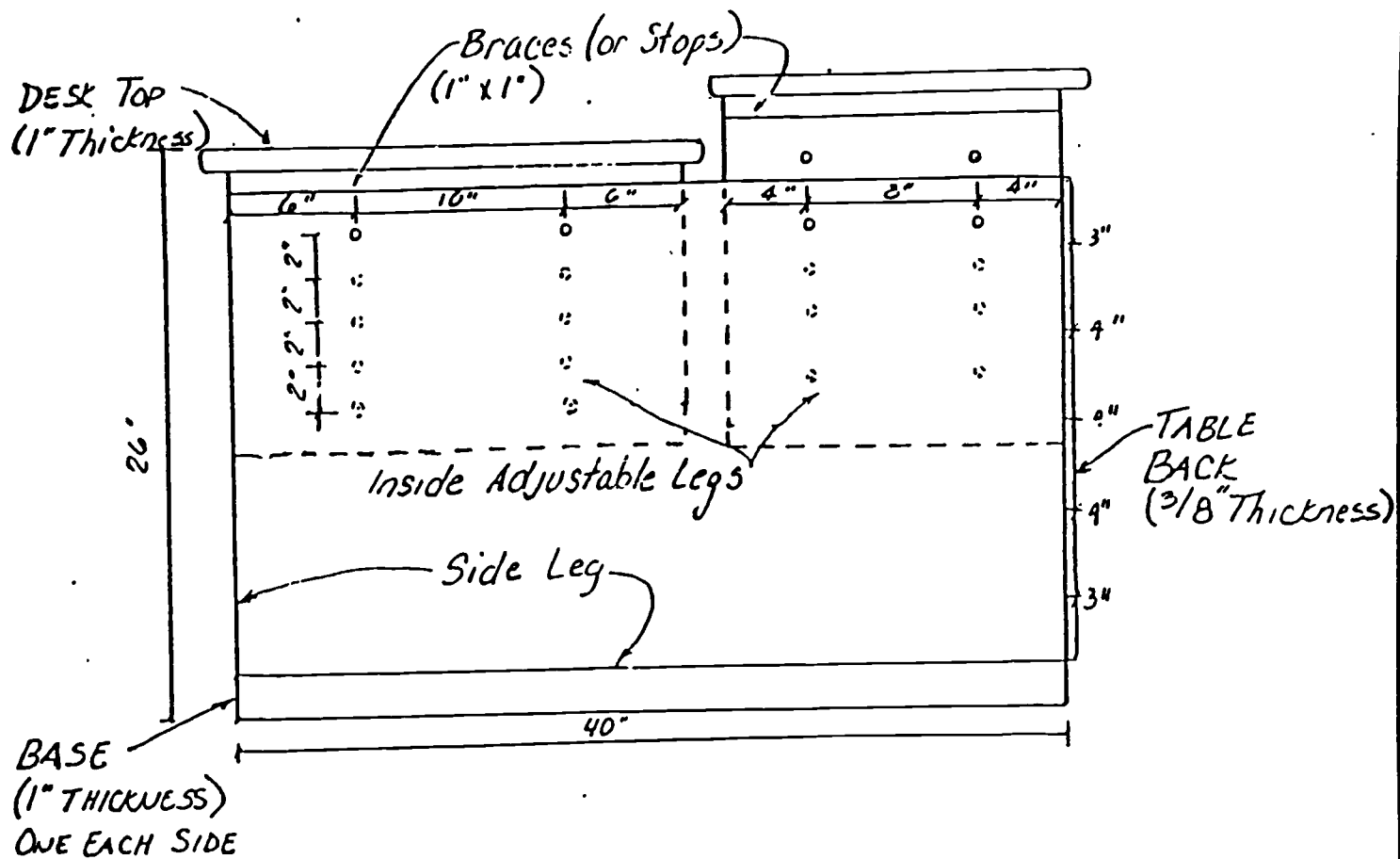Bolt Holes Not Shown, See Details

57

Braces (or Stops)
(1" x 1")

Desk Top
(1" Thickness)

6"   10"   6"   4"   8"   4"

2" 2" 2" 2"

3"

4"

4"

4"

Inside Adjustable Legs

TABLE BACK
(3/8" Thickness)

4"

Side Leg

3"

26'

40"

BASE
(1" THICKNESS)
ONE EACH SIDE

FIGURE 9
SIDE VIEW (LEFT & RIGHT)
1/8" = 1"

58

Adjustable Desk Table Top

Adjustable Computer Table Top

Braces (Stops)

Bolt Holes

Braces (Stops)

Bolt Holes

Side Leg (1" Thick)

Adjustable Leg (1" Thickness)

Adjustable Leg (1" Thickness)

Side Leg (1" Thick)

Back

Back

1" x 2" Foot

1" x 2" Foot
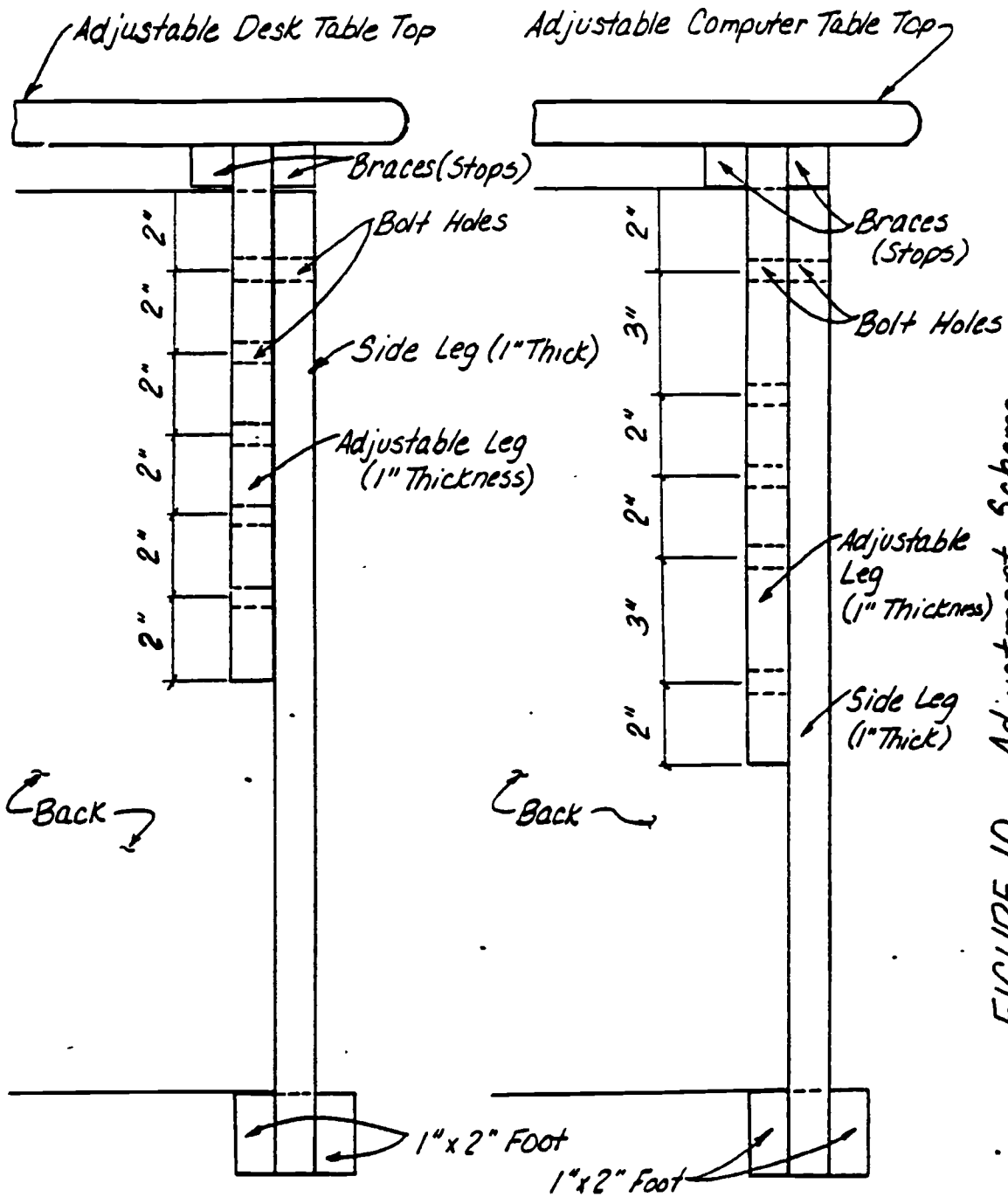
Desk Table Top Bolt Hole Details

Computer Table Top Bolt Hole Details

Scale : 1/4" = 1"

FIGURE 10 Adjustment Scheme