DESIGN FOR A SIT-STAND KITCHEN UTILIZING A MOTORIZED CHAIR

by

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INTRODUCTION

The study reported here is one phase of a project under way at Kansas State University, with the joint guidance of the Department of Family Economics, College of Home Economics, and the Department of Industrial Engineering, College of Engineering. Its purpose was to design a kitchen arrangement suitable for a person standing, and also seated to work on a motorized chair operating on a track under one counter. The idea for the motorized chair was created and developed by Dr. George P. Shrader, Head of the Department of Industrial Engineers.

The motorized chair enables the worker to transport herself the full length of the counter without the frequent alternate standing or sitting necessary in previous sit-stand designs. It is meant to relieve a person who desires or is compelled to be off her feet for any reason, yet who is not confined to a wheel chair. Thus, she or others could use it while standing or sitting.

The motorized chair, still in the experimental stage, is costly to produce and may be rejected for that reason. Furthermore, its use required redesign of the kitchen, as it is usually arranged. When the person used the motorized chair, it was necessary to eliminate practically all under-counter storage its full length, because of the need for knee room under the counter. This left only over-counter storage on that side. Storage for the items displaced from under the counter was supplied in a storage wall opposite the counter. In addition

to storage, the wall included the refrigerator and built-in oven as well as some items usually stored elsewhere in the kitchen.

Thus, the kitchen used in this study is a prototype of a corridor or Pullman design with storage cabinets and working surfaces arranged to be accessible to the maximum normal reach of a worker whether seated in the motorized chair or standing and walking in normal upright positions. Two goals, (1) efficient centers and (2) efficient arrangement among the centers, were important.

The counter in this kitchen is the area in which the manipulative processes connected with the traditional centers are done. Thus, the preparation center, the cook-top center, and the sink center are in a straight line. In addition to the problems posed by displaced storage, there are others related to center-connected storage because efficient use of any center requires that storage be related to it.

It is known that the sink is used extensively in preparation of food and that the preparation center has a close relationship to it. For this reason the sink center and the preparation center were located near the middle of the counter with the built-in oven directly behind it.

The objectives of this study were to design a kitchen and evaluate two locations of the cook-top center while preparing food both standing and sitting, using the criteria of:

1. The amount of movement necessary between the areas.
2. The number and height of the arm reaches necessary

to reach items stored on the various shelves.

3. The amount of time spent in each area.
4. A description of rotation and torsal distortion of the body necessary to reach items stored.

REVIEW OF LITERATURE

The review for this study was confined to literature explaining the reasoning behind the choices made for the relationship of the centers, the body mechanics involved in reaching and using the storage areas, and the accepted principles for their arrangement. Included are research findings and the philosophy which has developed because of research. In addition, established methods of procedure for measuring the effects of arrangements are reported.

Using human engineering and work simplification principles (McCullough, 1960, 1961; Wheeler, no date), wheel chair kitchens have been scientifically designed to locate storage facilities and counter heights to be within reach of persons in wheel chairs. Such designs provide knee-hole areas or eliminate under-counter storage completely except at the ends of the counter. Low counters limit use of the kitchen for the standing worker, however.

The use of the motorized chair in this kitchen imposed an unusual arrangement of the centers and the accompanying storage. In place of the U-, L-, or two-wall arrangement for the main centers, they had to be along one wall, with the oven and most of the storage behind them. The intended use of this kitchen

by workers both sitting and standing, and the elimination of under-counter storage necessary for knee room made demands on storage locations as yet untried. Findings of research were drawn upon for initial placement and organization of centers and storage of items within the centers.

Research on kitchen arrangements was begun in the early 1900's. Gray (1926) was influenced by the thinking of Frank and Lillian Gilbreth, considered to be the founders of work economy principles. Gray set forth many of the basic principles of arrangement used today: the selection and placement of large equipment, the forming of work centers, and the placement of utensils and supplies in the areas used. She contended that a "convenient kitchen is one in which the necessary work can be done with the least possible effort" (Gray, p. 1). Planning such a kitchen requires first having a clear idea of the routine jobs to be done, and then selecting and placing the needed equipment according to some criterion.

Engineers have given intensive study to the relations of the machine, the job, and the physical capabilities of the man to do the job. Home economists, beginning with the work done by Wilson (1937), have investigated and related heights of women and standards of working surface heights and other space units to specific jobs done in the dwelling, but primarily applied their findings to the design of kitchens and work places. It was not until psychologists and engineers, working in the armed services, crystallized the system concept of the

man-machine-work place that the importance of relating heights of the worker and the work area has been highlighted.

The system concept of design recognizes a group of components which serve a given set of purposes. It applies not only to equipment, but also to the importance of the man in the man-machine-work concept. That is, a design must start with a job and allocate the parts of the job to the human components and the machine capabilities if the man-machine-work system is to perform at its best.

Two kinds of anthropometric dimensions, static and dynamic, are related to the practical problems of designing for use. Static dimensions are taken with the body of the subject in rigid standardized positions, are easily obtained and translated into equipment design, but have not proven completely useful in design development. Dynamic dimensions are taken with the body in various working positions, are more complex and difficult to measure, but are more meaningful in design development. Both static and dynamic dimensions were used by Dempster (1955) in his attempt to find the outer limits of a space envelope for the purpose of locating controls. The subject maintained a posture with his legs, seat, and trunk in a static position with all movement coming from the arms and hands.

Functional arm reach, a dynamic dimension, is not a simple derivative of the anatomical arm length. It is a composite function of such factors as shoulder height, shoulder breadth, the length and width of the various segments of the upper torso,

arm and hand, and the range of motion at the shoulder, elbow, wrist and fingers. It can change with changes in the placement of the body, the location of the seat, the trunk, the legs, or of the hand and fingers.

Functional arm reach data are used to determine the outer limits of the work place or "space envelope." Reach measurements to any point on the edge of the space envelope vary in several important ways. The space envelope is affected by body size, proportions and position, and by confinement caused by clothing. It also varies according to the nature of the task and the design of the material, tool or control to be handled. Although it is difficult to derive generally applicable functional reach data, it is possible to develop data for a given task at a specified position.

Dempster (1955) found the space envelope or kinetosphere to have a specific size, shape and relation to the seat, trunk and legs.

> The space envelope is bounded by an intangible surface which in this instance represents the extreme range of motion of the reference point of the hand in different directions. The space itself is merely a region of potential position of the hand point. (p. 290)

Dempster also indicated that to modify the space envelope for different conditions, both the seat and the hand reference points must be identified.

In designing work centers or storage cabinets for household use as well as in designing the placement of materials, tools or controls for any machine, both types of anthropometric

measurements are required: static and dynamic. The human body, with its structure and mechanical function, occupies a central position in the woman-machine-work design as important as the man-machine-work relationship in industry and in space.

Improvements generally can be made in a work area by detailed job analysis of a specific manual operation. However, this information usually has little transfer value to another situation (Dempster, 1955). In kitchen design with an unlimited work area, the subject demands and uses more freedom of movement in determining the space envelope. She not only uses the arm and shoulder, but when she desires to extend her reach, she also moves forward and backward, utilizing her trunk, legs and, if seated in a chair, also her seat.

Centers and Storage Arrangements

Since the work of Gray and Wilson, much research has been done to determine the relation of the woman's dimensions to her workplace and to identify and describe the operations connected with preparing, cooking and serving foods, and cleaning up. Agan (1965) summarized their general thinking and opinions. The areas around the three basic pieces of kitchen equipment, the refrigerator, the range, and the sink, usually are designated as centers. These centers divide the kitchen into areas where tasks that require similar ingredients, utensils, or processing can be handled.

The arrangement of the centers should enable foods in preparation to move in production-line fashion from center to

center. There should be enough storage space at each center to hold the supplies and utensils used there, each article within reach where it first comes to use.

Operations performed at the range depend on the type of range used. If separate surface units and oven are used, the oven could be located adjacent to or near the preparation center. A surface unit could be located at the preparation center but should best be located near the sink center in the usual L-, U-, or two-wall kitchen.

Beginning with the assumption that the average height of the American housewife is about 5 feet 4 inches, Heiner and McCullough (1948), reaffirmed by Howard (1958) and Bratton (1959), determined the most efficient working "zones." The hands of a woman standing erect can range from about 28 inches to a height of 72 inches from the floor; and at waist level a span of 48 inches can be encompassed by the hands and arms. Thus, in a slightly oval zone, referred to as the "space envelope," 48 inches across and 44 inches up and down, the housewife can work without bending over, stooping, squatting, climbing, or excessive reaching. The researchers found that the supplies and utensils in most frequent use should be stored and used within this area. There, a woman of the assumed average height can reach without stooping or stretching and can use her body most effectively.

Howard (1958) found that the electric wall oven should be placed so that the floor of the oven is 32 inches from the

floor; the most used rack positions are between 35 and 40 inches. Later Grady (1962) found the optimum placement for the central shelf of the oven to be slightly higher. Beginning at 40 inches, the optimum location of the central shelf extended to 44 inches for good body mechanics and visual inspection for six subjects varying in body builds from 5 feet to 5 feet 9 inches tall and age range from 32 to 35 years. This range corresponded roughly to the elbow heights of the standing operators.

Present-day homes include more and more portable electrical cooking appliances which, for effective use, must be stored and used in relation to the body's capabilities. Grady (1965) investigated the storage placement of such large portable electrical cooking appliances as the portable oven, buffet fry pan, and portable sauce pan on the worker's body motions. Counter storage or slightly below counter height was found to be optimum for good body mechanics because of the weight of these appliances. If correct practices for lifting are observed, under-counter storage as low as 20 inches immediately below the place of use is acceptable.

Sitting or Standing to Work

Many homemakers, even in this era of labor-saving equipment and automatic appliances, spend long periods of time on their feet doing the work of the home and report fatigue as a result. Since many well homemakers cannot or will not stop in

the midst of a busy schedule to sit down and rest, to sit while working is often suggested as an acceptable means of relief with the reason given that sitting to work will "save energy."

The admonition to sit to work often is given without thought to the work arrangement in the homemaker's kitchen. If the seated arrangement is such that the homemaker must sit with her knees forced to the side, she is expending 0.08 calories per minute more than when standing facing the counter (Bratton, 1959, p. 22). Such twisting also puts an undue strain upon the muscles and produces a feeling of fatigue. If postural contortion and muscle strain are to be avoided, appropriate provision must be made in the design of the chair or stool and the accompanying work areas for seated work.

Bratton (1959) presented the following advantages or disadvantages of sitting to do household tasks:

1. Sitting to work may help to prevent some of the difficulty resulting from the shift of blood to the feet and legs.

2. Sitting to work will relieve some of the discomfort and fatigue of standing that results from excessive use of anti-gravity muscles and excessive stimulation of nerves connecting those muscles to the higher neural centers.

3. Short duration of most homemaking jobs and frequency of interruptions are observed external factors in favor of standing. (p. 37)

Time studies show that in meal preparation, most of the work time is broken up into small periods at a given center, with frequent trips between centers. According to Bratton (1959, p. 36),"Thorough study of the need and desirability in

terms of time at the unit /center/ or frequency of use is important before a manufacturer or an individual homeowner would design or build a work unit for seated work in the kitchen."

In her research report of 1961, Bratton summarized the chair-work-surface relationship in the light of what was known about women's dimensions and the body mechanics of working with the hands on or above a counter for such jobs as beating, cutting, ironing, kneading, or serving. Her interpretation was that the basic position of the upper arm for active work is vertical and close to the body, swinging freely through a relatively small arc from the shoulder joint. Her suppositions were:

1. The elbow joint is the chief center from which force is exerted by the hands in this kind of work.

2. A 90 degree angle between forearm and upper arm is the position of greatest strength and efficiency for work with the hands.

3. Force can be exerted <u>downward</u> by the hands more easily and effectively from a right-angle bend at the elbow than in any other direction. (p. 3)

Barnes (1944) found that if a chair is to be used, some consideration to the specifications of the chair is in order. The chair seat should be form fitting and sufficiently wide to accommodate the body. A shallow seat is needed to enable the body to bend at the hip when leaning forward. There should be an adjustable back rest, adjusted to the proper position to support the spine at the small of the back.

Methods of Evaluating Kitchen Design

Since the normal function of a kitchen is the preparation of food and the clean-up required, evaluation of kitchen arrangement and storage facilities can be determined best by the preparation of food. Various approaches have been made for evaluating kitchen design and there has been a progression of refinement of the methods used.

Information gathered by Ridder (1952) suggests that the following tasks are representative of the major work centers:

1. Paring and boiling potatoes (in water to represent cooking of most vegetables and some fruits).
2. Opening and heating a canned vegetable.
3. Frying eggs (requires less variety of motion than meat, but used the same equipment, work space, and method of cookery).
4. Mixing cake or cookies (frequent desserts using common equipment and methods of preparation).
5. Making and serving coffee (represents beverages made with hot water).
6. Cleaning up (for a complete picture of tasks connected with food).

Mize (1952) found that it was desirable for an entire meal to be prepared to measure satisfactorily the uses of spaces in kitchen design. She further suggested that both breakfast and dinner meals should be used.

Unstandardized procedures in the preparation of menus were found necessary to permit freedom while the work was in progress (Mize, 1952). An unstandardized procedure permitted the use of fewer subjects because it introduced differences in the work pattern similar to the use of more subjects.

Mize (1952) felt that more than one criterion was necessary in order to judge some aspects of kitchen design. She recommended the following criteria for testing different storage spaces and arrangements of equipment in kitchens:

> For testing storage space and devices:
> Energy index
> Angle of bend
> For judging organization of storage space:
> Distance reached
> Frequency of reach
> For locating special facilities:
> Time in area
> For studying floor plan arrangement:
> Number of times areas were used
> Space occupied by the worker. (p. 178)

The research techniques for the study of human costs of household work were defined further by Steidl (1963). She indicated that measures vary in the information they yield and provide means for analyzing different aspects of a problem.

Methods of measuring work are organized into three major groups: Movement, task, and evaluation. The study of movement in the work place involves determining the amount, pattern, and quality of movements, energy expenditure, and alignment of body parts. The task can be analyzed by investigating when and where greatest time costs occur, type of activity, and rate of work. The worker's evaluation /opinion/ is a subjective measurement, but often is very important.

Methods of Recording Data

In any research attempt, suitable methods of recording data are imperative to proper interpretation. Methods of recording data for descriptions and measures of work are summarized by Steidl (1963, p. 13) and reproduced in Table 1. In this table, written record (A) is a method of charting during the performance of the task to be evaluated. The record is permanent and immediately ready for analysis. The motion picture method (D) has more uses than any other method. The memomotion picture method usually is exposed at less frequent intervals than the usual rate of 16 frames per second in micromotion. The fewer frames exposed per second, the fewer details obtained. Time can be determined by a count of the number of frames exposed per second or by a clock placed within camera range.

Most of the data for measuring work can be used directly from the screen of the projected image. A "projection table" permitting analysis of the projected image at the analyst's writing level is desirable.

Several methods for determining travel distance between centers and during the entire meal process were investigated by Mize (1952). The most effective method was a trip chart on which was made a running record of the foot positions of the subject as she moved from place to place. Later, a scale model of the floor plan and a scale ruler were used to measure

Table 1.--Methods of recording data for descriptions and measures of work.

Descriptions and measures of work	Selected methods of recording data: Written Record	Stopwatch Readings	Still Picture	Motion Picture
	(A)	(B)	(C)	(D)
Movement				
Trips				
total number	x			x
distance	x*			x*
Pattern of movement				
between centers	x			x
sequence of centers	x			x
frequency of use of centers	x			x
part of center used	+			x
Alignment of body parts				
angle of bend				x
angle of arm lift				x
twists				x
Energy expenditure‡				x
Task				
Time				
total		x		x
trips		+		x
work at centers		x		x
parts of tasks		x		x
type of activity		x		x
Type of activity				
type	x			x
time		x		x
sequence	x			x
Rate of work	x + B**	x + A**		x
Evaluations				
Open-end questions	x		x + A	x + A
Rating scales	x		x + A	x + A

*Basic distance between places must be measured from a drawing or at the place, then multiplied by number of trips.

‡Standard equipment used to measure metabolic rate.

+May be possible but not tried at this experiment station.

(Steidl, 1963, p. 13)

**x + B or x + A. Use this method plus method B or method A.

the distance between the positions marked on the trip-chart. The distances were then tallied to obtain the distance moved.

DEVELOPMENT OF THE DESIGN OF THE KITCHEN

When this phase of the project started, the motorized chair and cabinet arrangements were in an undefined stage. Improvements on the chair required refinement of the mechanism to produce smooth motion, and changes in the seat and foot area to produce a body stance suited for forward active work, rather than the relaxed position used in automobile seats. Centers on the counter, with appropriate storage above them and in the storage wall, had not been located, nor had the best relationship of the centers to each other been established. In establishing centers it was necessary to consider the total arrangement for the kitchen, shelf heights, storage devices, and number and variety of items to be stored.

The Motorized Chair Assembly

The chair is suspended on a wall-hung track under the counter and slightly above the level of the floor. The track consists of a large cast-iron bar fitted with a series of gears, pulleys, rollers, and link chain. These are powered by a 115 volt, ½ horsepower capacitor motor and voltage regulator on a 120 voltage line to produce movement of the chair. Movement is activated by pressing the right foot pedal to move right, and the left foot pedal to move left. The pedals are mounted

in a platform area seven and one-half inches above the floor. The platform extends 15 inches from the front edge of the chair, and 23 inches from the pedestal of the chair.

The chair seat is 19 inches above the foot area or platform, and 12 inches below the counter top. The front edge of the chair seat is positioned directly below the front edge of the counter. The pressed wood seat is slightly formed, with a slope of approximately three degrees from front to back. A microhite mechanism enables adjustment of the height of the seat from 0 to 12 inches above its minimum height. A metal back rest (12½ by 6½ inches) may be adjusted four ways - up and down, forward and backward. For this study, it was adjusted to support the subject in the small of the back.

The chair seat is supported on a pedestal on which a pivot revolves the chair 360 degrees. A specially devised double-pivot also rotates the chair seat three inches forward when facing the storage wall. This places the subject in a closer working relationship with the storage wall, and in the proper chair-counter relationship when facing the counter. A metal foot rest 15 inches below the chair seat supports the feet when facing the storage wall.

Design of the Kitchen

Designing this kitchen was an integral part of the study since of necessity it departed so radically from conventional designs. If the chair is to fulfill its function of relieving

a worker from unwanted standing and walking, it must have a counter over it. This should be positioned to facilitate work while sitting, and, unlike counters designed for use of wheelchair patients, also enable work while standing. Because of the needed knee-room while seated (25 inches from the back of the chair seat and 7 inches above the seat of the chair), undercounter storage is practically eliminated. Likewise, the conventional range with the oven below the cook-top units and the usual dishwasher are unusable.

The solution chosen was a storage wall running the full length of the kitchen behind the chair and three feet from the front of the counter. It was close enough to be reached effectively either when seated in the motorized chair or when standing. It was available for storage of any equipment or supplies making up a part of a center. It was supplemented by storage in wall cabinets above the counter.

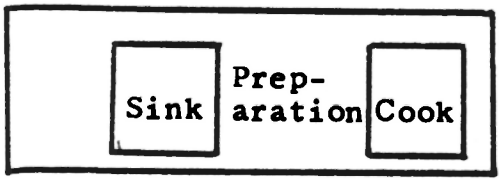
Development of Work Centers

Research on kitchen arrangement dictates the general order of arranging the work centers. The sink center is regarded as the most used center and should be the first to be located, generally close to the middle of the counter area. Built-in cook-top units should be located close to the sink, either to the right or left of it. The cook-top could also be located at one side or the other of the preparation center. The separate oven is most closely related to the preparation center and, if possible, should be adjacent to or near it.

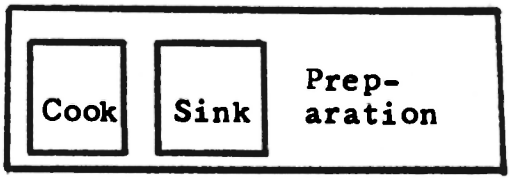
Preliminary studies were made to determine the location of the preparation center. Food was prepared while standing, and data from trip charts were taken. Standing positions were concentrated in such a manner as to indicate a location to the right of the sink was better than any other location for the preparation area. The oven was placed directly across from the mix area in the storage wall, accessible to both the sink and the preparation center.

It was not possible to determine the best location for the cook-top from these preliminary studies. However, two possible locations were considered: to the right of the preparation center, or to the left of the sink. In the first arrangement, designated Location 1, the arrangement progressed from left to right as counter, sink center, preparation center (or mix center), and cook-top center. In Location 2, the order of the centers, from left to right, was cook-top center, sink center, and preparation center.

Location #1



Location #2



After the location of the centers was determined, the kitchen was fully stocked with needed equipment and supplies. Based on the research by Heiner (1951) and Mize (1952), a modified list of the items most frequently found in kitchens

was compiled. These items were positioned according to the center with which they were associated and to recommendations concerning frequency of use, size, and weight of items. Shelves and items on shelves were arranged to make the best possible use of space. Items on the shelves and the height of the shelves were adjusted until all were considered to be either within easy or maximum reach of the subject.

The items connected with each of the centers were established as follows: those connected with the sink and preparation centers were considered as fixed, since their location was fixed. Those associated with the cook-top center and relocated when the center was moved were:

serving bowls
turning utensils
salt, pepper, and used fat container (range set)
cooking pans and lids
potholders

Preparation Center

The preparation center (Plate I) became very important as a general preparation area. The counter area, 38 inches by 24 inches, was limited by the inclusion of items generally found stored on it. A rectangular cannister set, electric can opener, and paper dispenser, stored at the back of the preparation center counter, reduced the 24-inch front-to-back working dimension to 15 inches. Their height also determined the position of the first shelf over the counter.

An electric Nutone "food center," consisting of a motor unit with controls, was installed in the counter top between the

EXPLANATION OF PLATE I

An overall view of the counter area of the kitchen with the cook-top in Location 1. Also visible are the track and the chair assembly.

PLATE I

sink and the preparation area. Individual attachments were a mixer, a blender, a knife sharpener, and a shredder-slicer for vegetables. These were stored directly across from the preparation area in the storage wall on a lazy-susan type shelf.

The Nutone "food center" was selected for use in the experimental kitchen for several reasons: First, a minimum recommended preparation counter space is 36 inches, the most desirable space being 42, or 48 inches if the counter serves two areas. Since it was necessary to conserve counter space in the experimental kitchen, the flush motor unit installation of this center provides an additional six inches of counter space when the food center is not in use. Second, items that need to be transported especially by physically limited workers, should be as light as possible. Since the motor unit is installed, only light weight attachments have to be lifted. Third, the amount of storage space required for these attachments is less than that required for the four different attachments if each had its own motor.

Sink Center

For testing this kitchen, a plastic tote-tray of a size approximating that of a sink was used. A working faucet was installed above it (Plate II). A small mid-shelf was installed at the rear of the sink area for necessary cleaning and scouring equipment. Certain specifications were considered desirable for the sink to be used in this experimental kitchen design.

EXPLANATION OF PLATE II

Use of the sink center. The mock dishwasher is visible above the faucet, and the tray for silver storage at the subject's left.

PLATE II


DIFFERENT PLACES CAN THE
EMCO DISHWASHER
IN YOUR KITCHEN?
JELL-O

1. It should be a shallow, one-bowl sink permitting room for the subject's knees.
2. The bottom of the sink should be insulated as a protection from hot water in the sink for the woman's thighs.
3. There should be a food disposer and drain in the right rear corner.
4. The faucet should be a one-spigot mixer type operated with a lever rather than handles.
5. A spray-rinse attachment should also be included.

Preliminary studies used cardboard mock-ups of front-loading and top-loading dishwashers. These types were too difficult for the subject to reach from the motorized chair and required under-counter area needed when the counter was in use. The type finally selected was available on the market but not purchased. It could be installed directly above the sink and flush with the front of the wall cabinets above the counter. In this position, it would be readily accessible while sitting or standing. The door is hinged at the bottom, and the racks slide out for easy loading. This dishwasher is 30 inches by 15 inches by 13 inches, holding a six place-setting of dishes by NEMA standards. Installation could also be at several other locations: recessed in the wall, set on a counter, installed under the counter, attached to the wall, placed below a built-in cook-top, or set on its own roll-about stand.

Cook Center

Only two large appliances were purchased for the testing, the cook-top and the built-in oven. The cook-top (shown in Plate III) is a drop-in electric model (32 inches by 20 inches)

EXPLANATION OF PLATE III

Use of the pull-out board at the south end of the counter.

PLATE III

with two standard heating units, a speed-heat unit and heat-minder unit in a staggered arrangement. The control dials are located in the front right-hand corner.

Special Devices

The sink and cook-top required a depth of four inches below the counter top for installation. This depth allowed clearance for the thighs of the subject when seated. A shelf, extending the full length of the counter, was installed at this level permitting storage of the silver, mix utensils, and a knife holder. Two small divided trays were used to simulate drawers. One was placed to the left of the sink to hold table silver, and one to the right of the preparation area to hold mix utensils. The knife holder was placed on a pivot on this shelf between the preparation area and the sink, making it accessible for use in either location.

During the preliminary practice sessions, it was found that the height of the counter caused some discomfort for rolling manipulations while the subject was seated. A pull-out board was devised and installed at the extreme right (south) end of the counter (Plate III). This board, complete with a fold-up leg secured with a magnetic catch, was installed so that when not in use, the under-counter remained clear for use of the chair the full length. The height of the board, 32 1/4 inches from the floor or 25 3/4 inches from the base of the chair platform, conforms to recommendations for lap-tables.

Storage Wall

The storage wall, installed opposite the counter, supplied storage space for food and equipment generally found under a counter. In addition, the refrigerator and the built-in oven were installed here (Plate IV).

Refrigerator: A mock-up refrigerator of plyboard (30 inches by 68 inches by 24 inches) was used throughout the experiment. The mock-up simulated a refrigerator with food storage area at the top and freezer at the bottom, with the doors hinged on the left. It was located at the south end of the storage wall, or on the far left end when facing the storage wall.

The requirements of this kitchen were such that some design features not available on the market were needed. Design characteristics considered desirable for the refrigerator include storage compartments, divided vertically instead of horizontally, with the food storage compartment on the right side and the freezer compartment on the left. The doors to both compartments would be hinged on the left sides to be usable by the seated worker in this experimental kitchen arrangement. Other door arrangements might also be tried. Roll-out or swing-out shelves or trays should also be available for each compartment.

Wall Oven: Until testing began, a cardboard wall oven was moved about to determine the best location. It was either a side-hinged or bottom-hinged door. In the final selection,

EXPLANATION OF PLATE IV

An overall view of the storage wall areas of the kitchen with the cook-top in Location 1. With the chair pivoted to the rear, she can readily reach most of the storage areas.

PLATE IV

both of these were rejected for the safety advantage of a door opening upward. A bottom-hinged door, when open, would rest just above the seated subject's thighs, presented a burn hazard to the arms and prevented turning from the oven to the counter. The side-hinged door was awkward because of the width of the door. A door opening upward eliminates all these difficulties and was found in an electric (Flair) wall oven.

The wall oven was installed directly across from the sink in the middle section of the storage wall at a height determined suitable for the subject both when sitting and when standing (Plate IV). The middle shelf of the oven, 46 inches from the floor, is two inches higher than recommended. The subject considered it a comfortable height while attending baking, but when attending foods under the broiler, this height was slightly above eye level and a little difficult to manipulate foods from a sitting position.

Storage Shelves: The general storage area, extending from floor to ceiling, was two feet deep and flush with the front of the refrigerator and oven (Plate V). This presented a continuous front surface.

Because of the depth of the shelves, care was necessary to enable the worker, both when standing and sitting, to reach all items placed there. Commercially available tote-trays, lightweight roll-out shelves, and lazy-susan shelves, used singly or stacked according to the needs of the planned contents, were installed.

EXPLANATION OF PLATE V

One section of the storage wall and the use of commercially available trays and shelves to facilitate maximum storage.

PLATE V

Vertical pan files have been recommended as economical use of space for storing baking pans rather than stacking in a drawer. Only a limited amount of space was found available for a file. One-eighth inch perforated hardboard was used for the top and bottom of the file with half-inch boards as the side pieces, all cut to fit exactly the space available. Dividers were wire from coat hangers placed in rows in the holes in the pegboard, and spaced to allow the pans to be removed and replaced easily (Plate VI, Fig. 1). The pan file was placed in the storage area to the north end of the experimental kitchen, away from the preparation center. This was not its best location according to use, but other more important items demanded the premium locations.

An eight-inch-wide space to the right of the oven was divided vertically to store large trays in the top section. The lower section was equipped with a disappearing rack for drying towels. A metal or plastic tray in the bottom would collect any moisture from the towels.

The wastebasket was placed on a lower shelf in the storage wall across from the preparation area. The height of the shelf above the wastebasket limited accessibility of the top opening. To correct this problem, blocks of wood taped to the bottom of the back of the wastebasket, tilted it forward and allowed easier access.

EXPLANATION OF PLATE VI

Fig. 1. The vertical pan file constructed from masonite and wire coat hangers.

Fig. 2. The knife rack swings out for easy use.

PLATE VI

Figure 1

Figure 2

Extra Convenience Features

This is a compact kitchen with important storage centered over the counter near the preparation and sink centers. Unused space remained which could be used for an opening. This could be a window if desired. In this kitchen it was thought of as a possible opening to the family room. Food could be passed through to a dining area (Plate I). The worker could also keep an eye on children playing and be a part of any family group gathered there.

An inner-house communication system was to be installed at the extreme south end of the kitchen. This would enable the worker to be in contact with family members in other areas of the house.

The location of the wall telephone and the planning center would depend upon the final location for the cook-top. If experimentation determines that the best location for the cook-top is in Location 1, the planning center and telephone could be placed in the counter space at the north end of the kitchen. If Location 2 is the best location, the planning center could be placed in front of the pass-through at the south end.

OBSERVATIONS CONCERNING THE KITCHEN

Previous research suggested a counter height for preparation areas of 31 or 32 inches for the average homemaker. Because of the way the chair and the track are constructed, the counter height in this kitchen was placed at 37 inches. The use

of the Nutone "food center," measuring ingredients, and slight stirring were regarded by the subject as comfortable. Chopping operations and the use of utensils requiring the hands to be from 5 to 7 inches above the counter, or where force had to be applied, were possible but considered to be uncomfortable. For more vigorous stirring, the subject desired a lower level which she achieved by stirring with the bowl in her lap.

In order to facilitate the handling of heavy items being placed in or out of the oven, a pull-out shelf should be designed and installed below the oven. This shelf would be used as a holding device until the food could be moved to the counter area.

Several devices for raising and lowering the shelves to within reach were considered but not constructed. The installation of a counter-balanced shelf assembly in which the whole assembly is easily raised or lowered, would enable the subject to reach the upper shelves with little stretching. The lower shelves of the storage wall will continue to present a problem in the present design unless limited to infrequently-used storage.

METHOD OF PROCEDURE

The objectives of this study were to design a kitchen and evaluate two locations of the cooking surface center, specifically as related to the sink center, in terms of dynamic anthropometry--work economy and body mechanics. The kitchen was

proposed to accommodate sit-stand operations, and it was necessary that the arrangements be usable for the worker whether sitting or standing. The choice of the testing procedures involved analysis of the type of data needed, and equipment and resources available.

The choice of subject, criteria for the food to be used, and the experimental procedure were determined. Other steps included the collection and treatment of data.

Selection of Subject

To be useful in designing arrangements, anthropometric data should satisfy the following criteria:

1. Samples should be large enough to yield reliable results reproducible from one sample to another.
2. The groups measured should be representative of the users of the arrangements.
3. Measuring techniques should be specified and standard.

Various limitations prevented meeting these criteria in entirety. A sample of between 50 and 100 is generally suggested as minimum, but for complicated experiments such as this, only a few are used. Because of the high cost and limited time available, only one subject was used. Duplicates of the several parts of the experimental procedures provided data for statistical treatment.

The subject chosen was a mature, experienced homemaker, free from health mobility or dexterity problems. This choice was made on the supposition that if any arrangement of the

kitchen should prove unusable for the well, mobile person, it would certainly also be unusable for the one needing to be seated.

The subject was 5 feet 4 inches tall, a figure recognized for some time as the average height for American women, although it is possible that the height is now greater. It is recognized that the body dimensions of an average height person could be expected to meet the requirements of only 50 percent of any population. However, it is known that body dimensions are distributed along a bell-shaped normal curve. For any population, most dimensions are included in the middle of the distribution, with fewer and fewer occurring toward the extreme. Ranges of dimensions rather than definite points are useful for many designs. It is possible that a person an inch or two taller or shorter than this subject would have served as well.

Although there is no one standard man or woman with given dimensions, standard measuring techniques, reported in Appendix D, were used when measuring this subject. The subject's measurements are reported in Appendix C.

For all filming processes, the subject wore a cotton house dress of a color that would be visible against the background. Black tape, sewed to the dress, marked the acromium process, the waist, the greatest protuberance of the hip line, the space across the shoulder blades in back, the side seams to the hip, and the center of the back following the spine. Additional

landmarks of black tape, attached to the subject before the filming processes, were: olecranon, the inner and outer elbow, the hairline at the outer point of the eye, the ear lobe, and the maleolous.

The subject's shoes were of a walking type with 1 1/2 inch heels. Squares of colored paper, taped to the heels of the shoes, enabled the recorder to determine quickly the position of the foot being recorded during the "trip charting."

A safety apron was designed to protect the subject from the possibility of burns while handling hot liquid such as when deep fat frying. The basic pattern used was designed for physically handicapped women (Scott, 1961). Adaptations were a short bib and side extensions around the corded area for a more extensive coverage (Plate VII). A moisture-proof fabric (Naugahyde) was selected for the apron, with a felted asbestos snap-out liner providing additional heat protection.

Menus

The criteria used in developing the menus were that they should range in degree of complexity of preparation, be interesting, illustrative of present-day living, and include normally prepared food, some pre-prepared food, and semi-prepared foods. The family prototype selected consisted of a family of four moderately active persons in the expanding family stage. Each menu was regarded as consisting of at least one-third of the daily nutritional requirements, and was prepared in a quantity

EXPLANATION OF PLATE VII

The subject wears the safety apron designed for protection against hot spills. Identifying colored squares on the heels of her shoes are also visible.

PLATE VII

to serve the family. The menus selected (Appendix A) include most of the operations normally performed during meal preparation. The operations, areas, equipment, and cooking methods are listed below:

Operations	Areas and Equipment	Cooking Methods
Rolling dough (soft and yeast)	Refrigerator	Water cookery
Flip or turn foods	Freezer	Fat cookery, deep fat and skillet frying
Use the mixer	Oven	Broil
Beat or mix by hand	Broiler	Bake
Measure liquid, dry and solid ingredients	Cook-top	
Crack eggs	Sink	
Ream fruit	Preparation center	
Chop	Dishwasher	
Pare	Pantry	
Slice	Deep fat fryer	
Grate	Blender	
	Mixer	
	Shredder-slicer	

The cooking procedures were programmed only to the extent of ordering the work for completion of the foods, serving, or holding. The subject was responsible for developing her own detailed step-by-step procedures to permit her to incorporate her own work habits and become thoroughly familiar with the kitchen arrangement and the recipes. Inasmuch as she was free to vary the procedures and did so, was believed to simulate the actions of more than one subject.

Practice sessions, with and without food, were held by the subject to acquaint herself with the location of the item needed, and the use of the motorized chair. The practice sessions also permitted the researcher to plan sequences to be

filmed and to gain practice techniques for collecting the data.

The research was concerned with meal preparation and serving, and a food was regarded as completed when it was placed in a serving dish and set on the pass-through. The clean-up was confined to that required for putting the counter in order. Used utensils were placed in the simulated dish washer.

Method of Collecting the Data

The types of data required were: (1) total walking or riding distances and time spent in preparation of each menu as shown by trip-charts, (2) body position, (3) number of reaches, and (4) length of time in each area for each food prepared as shown by memomotion film.

Random Order of the Menus and Separate Foods

Each menu and food, randomly selected by number, were prepared twice sitting and twice standing in each location of the cook-top. All testing for Location 1 was completed before beginning tests for Location 2.

Changing the location of the cook-top and replacing the counter area required services first from an electrician and then a carpenter for a potential of 112 times. Randomizing between Location 1 and Location 2 would have added so materially to cost, both in money and time, that this idea was abandoned. However, it is possible that procedures in Location 2 benefitted from learning (Appendix C).

Trip-Charting Process

The purpose of the trip-charting process was to obtain data on the total preparation time and amount of movement necessary when preparing complete menus, in both cook-top locations and when sitting and standing. The brown linoleum floor was marked off in one-foot squares with each square numbered and divided into four equal portions, labeled A, B, C, and D. The foot or chair could be located within a six-inch area (Plate XVIII, Appendix C).

The observer recorded on a trip-chart the subject's moves as she prepared each menu. As the subject moved from one area of the kitchen to another, the observer recorded the beginning and ending number and letter of the squares in order of sequence, and the beginning and ending time of preparation as shown by a wall clock. The foot being charted was identified with a square of red paper taped to the right shoe heel, and green taped to the left, the choice being unknown to the subject.

For sitting sequences, a large red arrow, suspended so that it cleared the floor, was taped to the pedestal of the chair. As the subject moved the chair in the preparation of the menus, the recorder noted the location of the arrow by identifying squares, and the beginning and ending time of the preparation on the trip-charts.

At the end of the menu charting process, an architect's scale ruler and a scale drawing of the floor of the kitchen (Plate XVIII, Appendix C) were used to determine distance

traveled between the center of any square noted and the center of the next square. The procedure was continued for the complete menu to obtain total distance traveled per menu. The time of preparation of menu was determined from beginning and ending time of cooking process.

Memomotion Film Technique

Technical advice for operating the camera was obtained from the Visual Aids staff, Department of Photo Services, on the location of camera, film, lighting, and lens settings. The equipment included a 16mm Bolex Paillard H. 16 Reflex camera with a variable shutter, using black and white Kodak Tri-X Type 7278 Reversal Safety Film. The camera was mounted on an adjustable tripod and positioned with the lens 5 feet above the floor and 20 feet from the south edge of the kitchen. The full counter and complete storage wall were within the camera range. The camera was manually operated for all of the filming processes, at a filming speed of 12 frames per second.

A General Electric Type DW-68 exposure meter was used to determine the following camera settings: f-8 or f-11 (depending upon the amount of auxiliary light), 1/30th second, and 1 to 30 foot distance.

Two Quartz-King 650 flood lights were used for illumination, one on top of the refrigerator unit to illuminate the north end of the counter area, the other to illuminate the storage wall. Additional light was from the ceiling light and the west windows of the research laboratory.

A chart hung on the side of the refrigerator identified the sequences being filmed by the film reel number, location of the cook-top, and the code number assigned to the food items being prepared. A clock on the counter, within camera range, indicated the length of time of the various manipulations and the total preparation time of the foods.

Each of the shelves and areas was identified by a number on white cards. These were visible from the camera and identified the areas in which the subject was working while being read from the films.

Activities Filmed: The memomotion technique was used to record two categories of activities. The first category was to study the motions used and the extent of frequency of reaches to reveal the suitability of organization of areas and storage devices. The second was to describe the subject's normal range of postural attitudes at rest and while reaching various shelf heights.

Individual Foods: Two methods were possible for the filming sequences: (1) preparing each of the foods making up the menu separately and then combining to analyze as a unit, or (2) preparing each of the menus in total.

The first method was employed. Since the memomotion technique was used to study motions and reaches used in preparing food, these are essentially the same regardless of the order performed. There were also management reasons for using this method. Each of the menus required approximately an hour

for preparation. The films were 100 feet long and ran for about 9 minutes, but the camera had to be rewound several times during this period. This meant change of films six times during the preparation of a menu and rewinding many more times. These interruptions might have occurred during a critical sequence, making the record inaccurate or incomplete. With the record of a menu on more than one roll of film, analysis would have been complicated. None of the foods prepared separately required more than 100 feet of film; none of the sequences were interrupted for more than camera winding; and more than one food preparation was often possible on each roll, since time required for cooking alone could be omitted.

A memomotion record was made in the motions performed by the subject during the preparation of each individual food, the portions of the operations and sequences having been determined from the practice sessions. The camera was operated for predetermined periods of time during the cooking process so that all manipulations, reaches, and transportation segments were filmed. The clock within camera range indicated the period of time spent on the operation.

Advance preparation for each of the filming sessions included the following steps: Supplies were checked before each filming session. The subject dressed and the anthropometric markers attached to her body. The camera and lights were positioned, the clock started, and the subject entered from the north end of the kitchen. The end of the session showed the subject leaving the experimental kitchen.

Body Positions: Single frames of the motion picture film were exposed as the subject stood erect, placed the palms of both hands on the front edge of the counter or shelf at about elbow height, then reached with first one hand and then two hands to the back of the counter and to each shelf above the counter and on the storage wall. Between each of the reaches the subject returned to the starting position. The pictures were snapped at the furthermost extension of the reach, the subject indicating if it was comfortable, slightly uncomfortable, or very uncomfortable. To maintain a right-angle profile, the reaches with one hand were performed with the hand closest to the camera. A record was made of each position filmed, the frame number, and the subject's reaction.

The above procedure was repeated with the subject in the motorized chair. The normal sitting posture was with the subject seated comfortably with her back against the back rest, and palms resting on the front edge of the counter or shelf at elbow height, both feet flat on the chair foot rest. After each reach, the subject assumed this position.

Film Analysis

For analysis of the film, the projector used was a Bell and Howell Time and Motion Projector Model 173 BD, equipped with a hand crank, Veeder Frame counter, heat filter, and calibrated speed controls. The hand crank permits viewing a single frame as a still picture. The frame counter records the number of frames advanced. It can be set at any point and

registers frames from 1 to 100,000 and subtracts when in reverse. The heat filter guards against film damage during single-frame projection without any light reduction. The calibrated speed control provides a speed range from 800 to 1500 frames a minute and includes settings for standard silent and sound film speeds. The frames were projected upon a white screen.

A custom-made device, consisting of a base, frame, and mirror, was used to project the film image onto a flat table surface for analysis of the body angles (Plate VIII). The projector rested on the base of the device, with the pipe frame extending to the front of the projector. The mirror was attached to the front of the frame at a 45-degree angle, and received the projected image and reflected it on a sheet of white posterboard on the table surface (Plate IX). The films were analyzed for the following information:

The angle of bend for testing storage space and devices.

The distance reached and the frequency of reach for judging organization of storage space.

Time in the area for locating special facilities.

Number of times the areas are used for studying floor plan arrangements.

Angles of Bend: In order to study the angle of bend (or body positions), the film images and the anthropometric points were traced onto white paper. A line was drawn between the points, indicating the malleolous or ankle bone and the greatest protuberance of the hip. A second line was then drawn to a

EXPLANATION OF PLATE VIII

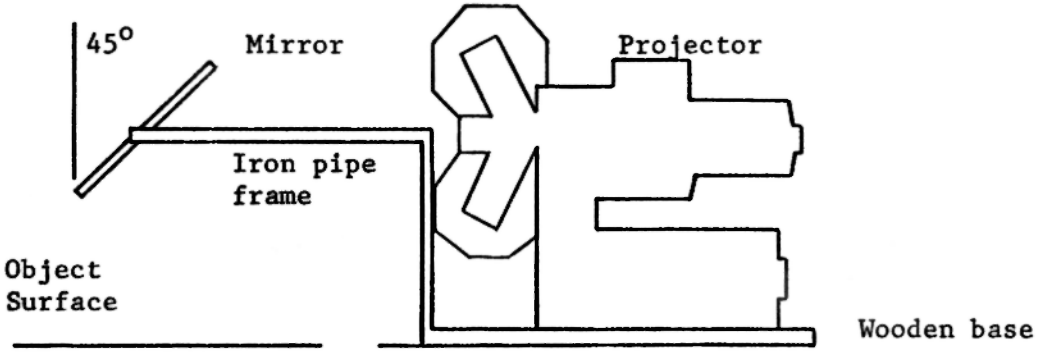
Custom-made device showing the position of the mirror as it reflects the film image onto a flat table surface, enabling easy analysis of the films.

PLATE VIII

EXPLANATION OF PLATE IX

Diagram of the projector arrangement and the position of the mirror used in analysis of the films.

PLATE IX


45°
Mirror
Projector
Iron pipe
frame
Object
Surface
Wooden base

point on the frame of the spectacles. A protractor measured the angle formed.

Distance and Frequency of Reach: Chart forms were prepared listing all of the areas and the numbers assigned to the various shelves. As the films were projected, one frame at a time, the number of reaches to each shelf were counted and recorded. This was done for each individual food, duplication, location, and sitting and standing. Tallies were collected into menu form for evaluation.

Organization of Storage Space and Devices: The time in the area was determined by projecting the films, one frame at a time, and reading and recording the time from the clock for the individual foods, duplications, locations, and for sitting and standing. When the food tallies were collected to menu form, the areas where the greatest amount of time was spent could be determined. From these data, it was also possible to determine the number of times the areas were used. Time spent in manipulations on the front 15 inches of the counter area was also determined from this information.

RESULTS AND DISCUSSION

Data are presented evaluating two kitchen arrangements for use by a worker standing or seated in a motorized chair. The evaluations were based on principles of dynamic anthropometry--work economy and body mechanics recommended for the female worker.

Work economy involved the distance traveled, time spent, number of times areas were used in preparing menus, and arrangements of the centers. Body mechanics involved the number and height of the reaches to the shelves and a description of the body positions required to perform the operations.

Time Spent and Distance Traveled in Preparing Menus

The trip chart method was used to determine the distance traveled in feet and the amount of time in minutes required for the preparation of each menu. Two duplications were made for each menu for each location while sitting and standing.

Two hypotheses were tested:

1. The location of the cooking unit is not related to the time spent in preparation of the menus.
2. The location of the cooking unit is not related to the distance traveled.

Time Spent, Hypothesis 1

The data in Table 2 indicate that for the three menus, with two duplications each, the total preparation time for Location 1 was 662 minutes, and for Location 2, was 615. The Analysis of Variance test (Table 3) indicated that this difference in time was not significant. Thus, from the standpoint of time saved, neither location had a significant time advantage. It is possible that the subject profited from learning experiences of the testing done in Location 1, but the learning experiences were not measured or accounted for.

The question arose as to whether preparation while standing had a time advantage over preparation while sitting. The total

Table 2.--Time spent and distance traveled in preparing three menus, as indicated by trip charts.

Menu and Replication Number	Time Spent in Minutes				Distance Traveled in Feet			
	Location 1		Location 2		Location 1		Location 2	
	Stand	Sit	Stand	Sit	Stand	Sit	Stand	Sit
Menu A								
#1	56	65	50	60	273.8	185.5	405.7	260.0
#2	53	55	50	56	305.7	178.5	355.6	229.0
Menu B								
#1	60	67	46	46	230.1	175.5	295.7	174.0
#2	44	60	65	60	266.7	148.0	297.2	169.0
Menu C								
#1	50	57	40	52	181.2	158.5	295.8	178.0
#2	35	60	40	50	263.7	185.5	258.8	179.0
Total	298	364	291	324	1521.1	1031.5	1908.8	1189.0

Totals:	Minutes	Feet
Location 1	662	2552.6
Location 2	615	3097.8
Standing	589	3430.9
Sitting	688	2220.5

Table 3.--Analysis of variance of menu preparation time by cook-top location, measured by trip chart analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	92.04
Position	1	408.38*
Menu	2	163.04
Location by Position	1	45.38
Location by Menu	2	1.79
Position by Menu	2	43.88
Location by Position of Menu	2	34.13
Duplicates	12	51.04
Total	23	

*$P < 0.05$; df = 12.

time spent in preparing the three menus was 589 minutes for the standing position and 688 minutes for the sitting position. This 99-minute difference was significant at the 0.05 level (Table 3). A part of this difference might be accounted for in the speed with which the motorized chair was programmed to operate. To insure a smooth operating performance while running, stopping, and starting, the chair moved at a speed of 2 miles per hour, whereas the average walking speed of a woman is considered to be 2.5 miles per hour. In addition, as will be shown in the memomotion study, more time is required to perform when sitting than when standing.

Distance Traveled, Hypothesis 2

The total distance traveled (Table 2) for Location 1 was 2,552 feet and for Location 2 it was 3,097 feet. The difference of over 545 feet is statistically significant at the 0.001 level (Table 4).

Table 4.--Analysis of variance in distance traveled by location of cook-top, measured by trip chart analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	12384.22***
Position	1	60939.65***
Menu	2	9125.68***
Location by Position	1	2207.62
Location by Menu	2	1468.16
Position by Menu	2	1158.66
Location by Position by Menu	2	49.92
Duplicates	12	647.79
Total	23	

***$P < 0.001$; df = 12.

The distance traveled when standing totaled 3,429 feet and when sitting totaled 2,220 feet (Table 2). The difference of 1,209 feet is significant at the 0.001 level.

The lesser difference in distance traveled when sitting might be partly accounted for by the ways the subject worked when standing or sitting. When standing, she walked not only along the front of the counter, but also at angles toward the storage wall when she needed something there. Some of the distance walked included shifts of the position of the feet from side to side or forward or backward of no more than six inches while working. When seated on the chair, however, she moved along the distance of the counter, and when she needed to use the storage wall she was rotated toward it by the double pivoting device under the seat. Also, while on the chair, she had a tendency to lean one way or the other to reach the outer

extremities of her work area or moved the chair only slightly (less than six inches), and this caused further reduction.

In the design of the experiment, the menus were planned from a high complexity of preparation (Menu A) to a low complexity of preparation (Menus B and C). This was done to provide a full scope of activities and to indicate the effect of varying degrees of complexity of preparation on the distance traveled.

The Analysis of Variance (Table 4) showed, at the 0.001 level of significance, that distance traveled by the location of the cook-top is affected by menus. From the Least Significant Difference test it was determined if there was a difference in menus. Menu A was significant at the 0.05 level, indicating that the more complex the menu, the greater the distance traveled. Menus B and C were equal and not significant.

The location of the cook-top center is not significantly related to the distance traveled. Location 1 is the better location for the cook-top. Sitting to work reduced the distance traveled, but increased the time required for preparation. If the worker wanted to sit, or had to sit to work, she would have to accept the fact that it would require a longer time than standing.

Use of Centers

Consideration was given to the extent of use of each of the centers as the location of the cook-top was moved and as

the subject stood or sat for the preparation. Of special interest was the extent of manipulations occurring at each center and the division of total time between manipulations and travel between the centers. The memomotion technique of recording was employed.

Certain tests were applied to determine: (1) if one of two possible variations in location of the cook-top on the counter was more desirable than the other, and (2) if the arrangement of the storage at each center was such that the most used items were placed in the most advantageous locations in terms of number and height of reaches. The following hypotheses were tested:

The location of the cook-top has no effect on:

a) amount of time spent in each area.

b) number of times each area is used.

c) amount of time used in travel in the preparation of the menus.

d) time spent in manipulation occurring on the counter areas.

e) number of manipulations occurring on the counter areas.

Time Spent in the Areas

The amount of time spent in each area and the number of times an area is used indicate the relative importance of the areas of a kitchen and their relationship to each other. An efficient arrangement is one in which the greatest amount of time is spent in an area with the least number of trips in or out of it. An arrangement such as this has the effect of

reducing travel distance and travel time necessary in menu preparation.

To determine the amount of time spent in the areas and the number of times the areas were used, the memomotion films were projected and analyzed frame by frame. The number of times each area was used were counted, and the amount of time while there was determined by the readings on the clock. Time was counted as long as the subject remained in the area, even though she may have reached into an adjoining area during an operation or manipulation.

In Table 5, Locations 1 and 2 refer to the placement of the cook-top on the counter. The counter itself was designated North End (of the counter), Sink Area, Preparation Area, and South End (of the counter). Regardless of the location of the cook-top, the subject used all of the counter areas in the preparation of the menus. That is, when the cook-top was not in Location 1, the space vacated was available for use. Likewise, when the cook-top was not in Location 2, the space vacated was available for use. The vacated areas are indicated as South End and North End in Table 5 and succeeding tables and text.

The areas in Location 1 were used a less number of times (161) than Location 2, and 77 more minutes were spent there (Table 5).

The time spent in the areas in Location 2 was significantly less (at the 0.01 level) than in Location 1 (Table 6). Thus,

Table 5.--Length of time spent in each area and the number of times the areas were used, by location and position, as measured from memomotion film.

Areas	Time Spent in Minutes				Number of Times Used			
	Location 1		Location 2		Location 1		Location 2	
	Stand	Sit	Stand	Sit	Stand	Sit	Stand	Sit
North End	8.1	13.1	5.9	6.7	25	61	77	64
Sink	16.1	18.0	13.9	21.3	46	89	104	103
Preparation Area	149.5	146.8	122.1	102.8	174	189	206	177
South End	10.5	13.3	11.8	19.9	80	61	61	59
Pantry	1.3	1.9	1.7	1.9	32	29	35	34
Oven	7.6	9.9	7.8	10.8	63	60	63	56
Beside Oven	2.5	2.6	3.2	2.3	68	84	89	72
Refrigerator	1.9	2.5	2.2	2.3	50	51	52	54
Roll Board	0.0	23.3	0.0	16.1	0	17	0	8
Waste Basket	0.0	0.0	0.0	0.0	37	46	55	49
Total	198.0	231.4	168.6	184.1	575	687	747	676

Totals:	Minutes	No. of Times
Location 1	429.4	1262
Location 2	352.7	1423
Standing	366.6	1317
Sitting	415.5	1363

Table 6.--Analysis of variance of length of time by location of the cook-top, as measured by memomotion analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	147.23**
Position	1	59.63*
Area	9	6185.85***
Location by Position	1	8.03
Location by Area	9	130.39**
Position by Area	9	57.03**
Error	9	10.48
Total	39	

df = 9
*P < 0.05
**P < 0.01
***P < 0.001.

the hypothesis that the location of the cook-top has no effect on the amount of time spent in each area was rejected. Treatment of the means by the Least Significant Difference test from Location 1 showed several differences by areas to be significant at the 0.05 level: between the sink and preparation area, preparation area, and cook-top (South End). These form the core of this kitchen in terms of the amount of time spent (Tables 6 and 7). These were also the areas observed to be most used when judged by the trip-chart analysis.

When the cook-top was moved to the north end for Location 2, the time spent in each of the areas increased. This presented a more balanced use of the areas (from Least Significant Difference test, Tables 6 and 7), but indicated more travel.

Table 7.--Least significant difference of length of time means spent in each area by location of cook-top and position.

	L x A Means		P x A Means	
	L 1	L 2	Stand	Sit
North End	10.59	6.29 *	7.00 *	9.87 *
Sink	17.31 *	17.64 *	15.28 *	19.67
Preparation Area	148.15 * *	112.47 *	135.81 * *	124.81 *
South End	11.89 *	15.84 *	11.16 *	16.07 *
Pantry	1.64	1.80 *	1.48	1.96 *
Oven	8.72	9.29	7.66	10.36 *
Beside Oven	2.59	2.74	2.87	2.45
Refrigerator	2.19	2.25	2.07	2.38
	21.47	17.63	18.33	20.77

LSD = 7.323

*$P < 0.05$.

Number of Times the Areas Were Used

The hypothesis that location of the cook-top has no effect on the number of times each area was used was rejected at the 0.001 level. The areas of Location 1 were used less (Table 8).

Table 8.--Analysis of variance of number of times areas were used, as measured by memomotion analysis.

Source of Variation	df	Mean Square
Location	1	608.40
Position	1	52.90
Area	9	9076.83***
Location by Position	1	792.10*
Location by Area	9	203.46
Position by Area	9	96.62
Error	9	133.60

df = 9

*$P < 0.05$

***$P < 0.001$.

From the Least Significant Difference test of the means, the greatest interaction was between the Preparation Area and the Sink Area for Locations 1 and 2, positions standing and sitting, as shown in Table 9.

The area effect is significant at the 0.001 level. Moreover, the major area effect comes from the differences between the Preparation and Sink Areas, as shown by the asterisk in Table 9 (A).

The Location by Position interaction is shown in Table 9 (B). The number of times Location 2 is used in the standing position is significantly greater than for Location 1; but

Table 9.--Least significant difference of number of times used in each area by location of cook-top and position means.

(A)

Areas	Means
Preparation	186.5 *
Sink	85.5
Beside Oven	78.2
Cook-top L 1	65.2
Oven	60.5
Cook-top L 2	5.7
Refrigerator	51.8
Wastebasket	46.8
Pantry	32.5

LSD = 18.5
*P< 0.01

(B)

L x P Means

	L 1		L 2
Stand	57.5	*	74.2
Sit	68.7		67.6

LSD* = 11.7
*P < 0.01

there is no difference in this regard when in the sitting position.

Neither of these two tests, the amount of time spent in an area and the number of times the areas are used, can be considered a complete test of the kitchen arrangement by themselves. But from these two tests, it should be pointed out that although usage of the areas was greater for Location 2, the greater total amount of time was spent in the areas in Location 1. If kitchen areas are arranged so more time is spent in an area with fewer trips to other areas, a compact kitchen arrangement will result and intra-area time minimized. By this criterion, the cook-top in Location 1 would be the better arrangement.

Time Used in Travel

The data for the amount of time used in travel were obtained from memomotion analysis. The sums for the length of time spent in each area and the amount of time required for cooking the foods were known from calculations. The total amount of time required was obtained by use of the beginning and ending readings of the clock in the camera view. The sum of the cooking time and time in area was subtracted from the total time to obtain the amount of time spent in travel (Table 10).

Table 10.--Length of time spent in minutes for cooking and traveling, and time spent in the areas.

Time	Location 1		Location 2	
	Stand	Sit	Stand	Sit
Time in Areas	198.0	231.4	168.4	184.1
Cooking Time	219.3	220.3	381.3	439.2
Travel Time	35.9	39.6	38.1	41.8
Total	453.2	491.3	578.8	665.1

The hypothesis was posed that the location of the cook-top had no effect on the amount of time used in travel in the preparation of the meals. The data were treated with the Analysis of Variance (Table 11).

Location of the cook-top had no significant effect on the amount of time used in travel in the preparation of the menus. The only source of variation that was significant was the menu (0.05 level). The means of the menus were treated for the

Table 11.--Analysis of variance of the amount of time used in travel, as measured by memomotion analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	0.83
Position	1	2.26
Menu	2	28.80*
Location by Position	1	0.00
Location by Menu	2	5.49
Location by Position by Menu	2	0.72
Position by Menu	2	4.23
Duplications	1	0.63
Error	11	5.53
Total	23	

df = 11

*$P < 0.05$.

Least Significant Difference. Menu C, the simplest, required less travel time than Menus A and B, which were equal.

Manipulations on Counter Areas

Although time at each of the areas had been analyzed, the amount of manipulations there was also investigated. Manipulations are defined as any job or operation performed with the hands, or by mechanical means with hands and utensils. It was considered important to study manipulations because areas in which they occur, to a considerable extent, require a complicated arrangement of equipment and supplies to service them, and bear an important relationship to other areas.

Of special interest was the extent of manipulations occurring at each of several counter areas, as measured by the number of times they occurred and the total amount of time

given to manipulations in the preparation of a menu. Findings from this effort tended to substantiate and enlarge upon those concerning the time spent at each area.

The portion of the counter area used in enumerating the manipulations involved the front 15 inches of the counter and the space of about 12 inches above the counter surface. Reaches into shelves or storage areas, or beyond the front 15 inches were not counted. Locales for manipulations were the North End (Location 2), the Sink Center, the Preparation Center, the South End (Location 1), and the Roll Board Area. (The Roll Board Area data are included in Table 5, but not included in statistical analyses because they were used only in the sitting sequences.)

The amount of time spent performing manipulations, and the number of times manipulations occurred are shown in Table 12.

Two hypotheses were tested: (1) The location of the cooking-top has no effect on the amount of time spent in manipulations on the counter areas; and (2) the location of the cooking-top has no effect on the number of times manipulations occurred on the counter areas.

Time Spent in Manipulations: The hypothesis that the location of the cooking unit has no effect on the amount of time spent in manipulations was rejected. However, both Location and Position by Area were significant at the 0.01 level (Table 13).

Table 12.--Time spent in manipulations on the counters in each area and the number of times the counters were used for manipulations.

Areas	Time Spent in Minutes				Number of Times Used			
	Location 1		Location 2		Location 1		Location 2	
	Stand	Sit	Stand	Sit	Stand	Sit	Stand	Sit
North End Counter	4.8	10.3	5.5	17.0	18	15	39	39
Sink	13.7	21.8	17.5	19.8	33	55	50	52
Preparation	142.9	132.5	108.6	99.0	109	110	111	105
South End Counter	13.1	14.1	17.2	18.1	51	50	42	39
Roll Board	0.0	20.1	0.0	15.0	0	11	0	7
Total	174.5	198.8	148.8	168.8	211	241	242	242

Totals:	Minutes	No. of Times
Location 1	373.3	452
Location 2	317.6	484
Standing	323.3	453
Sitting	367.7	483

Table 13.--Analysis of variance of time spent in manipulations, as measured by memomotion analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	77.45
Position	1	49.31
Area	4	4678.43
Location by Position	1	0.45
Location by Area	4	129.08***
Position by Area	4	51.35**
Location by Position by Area	4	2.94
Duplicates	20	1.47
Total	39	

df = 20

**P < 0.01

***P < 0.001

The means for the length of time in the areas by location was calculated and treated for the Least Significant Difference. The mean time for all counter areas for Location 1 was 88.3 minutes, and for Location 2, 75.7 minutes, indicating that more time was spent in manipulations in the areas when the cook-top was in Location 1.

The Preparation Area was designed to be the locale of the most manipulations, with the other centers related to it. The Preparation Area was the only area found to be significant (0.05 level) and favored Location 1. For both Locations 1 and 2 the time spent in manipulations at the Preparation Area was about eight times greater than the time spent in manipulations at the Sink Center, the next in order of use. The shorter length of time spent at the Preparation Area in Location 2

would appear to indicate that the subject dispersed her efforts so spent less time at the Preparation area. At both locations, there was a significant relationship (0.05 level) between the Sink Area and the Preparation Area, and the Preparation Area and the South End (Location 1). In Location 1, an additional relationship existed (0.05 level) between the North End and the Sink Area.

When Position by Area was considered, more time was spent in manipulations while sitting than while standing. The significant differences (0.05 level) occurred in the North End and the Preparation Area. At the North End more time was spent in manipulations while sitting, but in the Preparation Area more time was spent in manipulations while standing.

Several theories might be advanced for these differences. The subject may have had more difficulty with manipulations while cooking at the North End, since the length of time spent there was significantly greater. While standing at the Preparation Area, either she had more difficulty or she preferred doing things there and spent more time doing it. Analysis of the subject's movements while she worked offers another clue. The length of time in the areas was calculated from the chair and feet positions, not the positions of the hands. As the subject worked standing, she shifted one foot to the right or left about six inches, remaining in the same area, and then reached into the adjoining area. When she was seated, she had a tendency to move the chair to the left or to the right, thereby placing her in a different area.

There was a significant relationship (0.05 level) between each of the areas while standing, and between the Sink Area, the Preparation Area, and the South End while sitting.

Number of Times Areas Used for Manipulations: The hypothesis that the location of the cook-top had no effect on the number of times manipulations occurred on the counter areas was not rejected (Table 14). However, there were significant interactions between the locations by Area (0.001 level) and position by area (0.01 level). There was more significant interaction between centers for Location 1 than for Location 2. In Location 2, the North End and Sink Area were used significantly more than in Location 1. The South End was used the least for Location 2, with the Preparation Area equal for both locations. As in previous data involving the use of the areas, it must be remembered that the cook-top was placed in the North End for Location 2, and consequently increased the use of this area at this time. The Preparation Area was the most important, receiving almost twice the amount of use as the Sink Area, the next most important area. For both locations, there was a significant (0.05 level) relation between all the areas.

Significant interactions between areas when standing and sitting were similar to those of Locations 1 and 2. There was a significant difference at the sink (Table 15).

Position by Area indicated a significant difference (0.05 level), with the Preparation Area being used over twice as often as the other areas. The Sink Area was used more times by the subject when she was sitting than when she was standing.

Table 14.--Analysis of variance of the number of times counter areas were used for manipulations, as measured by memomotion analysis.

Source of Variation	Degrees of Freedom	Mean Square
Location	1	25.60
Position	1	22.60
Area	4	2996.09
Location by Position	1	22.50
Location by Area	4	76.29***
Position by Area	4	26.06**
Location by Position by Area	4	9.31
Duplications	20	0.67
Total	39	

df = 20

**P < 0.01

***P < 0.001.

Table 15.--Least significant difference of number of times areas used for manipulation means by location of cook-top and position.

Areas	L x A Means		P x A Means	
	L 1	L 2	Stand	Sit
North End	8.25 *	19.50 *	14.25 *	13.50 *
Sink	22.00 *	25.50	20.75 *	26.75
Preparation	54.75 *	54.00 *	55.00 *	53.75 *
South End	25.25 *	20.25	23.25	22.25

LSD = 3.394

*P < 0.05.

All other areas were non-significant, and used equally while sitting or standing. However, when totals of the means were

considered, the areas were used the least number of times by the subject when she was standing. Again, this difference could be caused by the subject reaching into adjoining areas while standing, and moving the chair into an adjoining location when she was seated (Table 15).

There was a significant difference (0.05 level) between each of the areas for sitting and each of the areas for standing. Apparently, this would indicate a good arrangement of the centers for manipulations whether the subject was sitting or standing.

Body Positions

The torso is the heaviest part of the body, and keeping it in balance and nearly erect is an important factor in the mechanics of posture as well as in the amount of energy expended when performing a given task. When using the arms and hands, very little shift in the torso is required at certain levels of the body. As the reaches extend above or below this level, distortion of the body stance, as measured in angles of body bend, occurs. Changes in body stance have been found to be associated with changes in energy consumption. The attempt here will be to determine the number and height of reaches and to describe the effects of various positions of the arms in reaching up, down, and forward within reach envelopes normally used in the kitchen. The angle of body bend may be as important an indicant of exertion as energy cost measured in calories.

If the arm operated from a single joint at the shoulder there would be little doubt of the dimensions of the reach envelope, as indicated by height of shelves or depth of counter, as they would be determined by the height of the shoulder, length of the arm, and the extent of bending forward from the waist or hips. However, the movements of the arm are controlled by movements within the shoulder. These are governed by four shoulder joints, each of which has great flexibility (Kennedy, 1964). For this reason it is not possible to distinguish a stationary center of rotation for more than a very limited range of movement. In fact, any joint center is temporary and migrates as the shoulder performs. It is also known that restriction of any one of the joints by any means results in reduced reach capability. Therefore, it is difficult to pre-determine the shape of the reach envelope at any arm position. If only one arm is used, the reach envelope has one shape; if both arms are required, the shape is different. It is possible to establish functional arm reaches either way.

It should be pointed out also that as the various parts of the shoulder are rotated in the performance of a reach with either or both arms, that the posture of the whole torso changes. Indeed, the dimensions of the reach may be extended by some elasticity in the waist area for some people, either standing or sitting, and by a tip-toe stance when standing.

The range within which the arms function easily without much distortion for the body stance is believed to be fairly

narrow for the average normal figure: between 30 and 40 inches from the floor. The 10 inches above and below this range are between 49 and 59 inches, and between 30 and 20 inches has been regarded as reasonably comfortable but with more distortion. Below 20 inches and above 59 inches is regarded as definitely uncomfortable and with corresponding distortions (Beyer, n.d.).

Number and Height of Arm Reaches

The existing shelves in the kitchen were specified as being in five-inch intervals of height. The number of reaches in each interval was counted frame by frame.

Table 16 lists the number of reaches by height, location, and position. The total number of reaches for Location 1 was 2,038 and for Location 2 was 2,220. Standing required 2,024 reaches and sitting 2,234 reaches. Since one of the criteria for a good kitchen arrangement for work economy and body mechanics indicates the least number of reaches as the most desirable, it would appear that the better arrangement would be the use of Location 1. When standing, the arrangement required fewer reaches than when sitting.

Percentages were calculated for the number of reaches above 59 inches, those between 20 inches and 59 inches, and those below 20 inches. The number of reaches in the comfortable zone of 20 to 59 inches was 89% of all reaches. From 1.5% to 4.4% of the reaches were above 59 inches and 4% to 5% below 20 inches.

Table 16.--Number of reaches by height, location, and position, as shown by memomotion analysis.

Range in inches	Location 1		Location 2	
	Stand	Sit	Stand	Sit
69 - 65	12	17	33	31
64 - 60	3	7	15	11
59 - 55	2	2	2	2
54 - 50	142	172	199	202
49 - 45	140	128	140	145
44 - 40	69	86	76	71
39 - 35	296	323	336	331
34 - 30	106	203	132	177
29 - 25	0	0	0	0
24 - 20	118	120	109	108
19 - 15	36	50	54	46
14 - 10	0	0	0	0
9 - 0	4	2	0	0
Total	928	1110	1096	1124

	Stand	Sit	Total
Location 1	928	1110	2038
Location 2	1096	1124	2220
Total	2024	2234	4258

It was hypothesized that the location of the cook-top is not related to body mechanics in terms of the number of arm reaches. The hypothesis was rejected for the standing but not sitting positions. Chi-square values (Table 17) ranged from 0.05 to 0.001 levels of significance, and the larger number of reaches occurred in Location 2. All non-significant Chi-square values occurred when the person was sitting, except in one case. The exception was for all reaches greater than 49 inches and indicated a significance of 0.05.

Table 17.--Chi-square of number of reaches by height, location, and standing or sitting.

Position	Location 1 No. reaches	Location 2 No. reaches	Total No. reaches	X^2
Height of Reaches Regarded as Most Comfortable (Greater than 30 and less than 49 in. from floor)				
Total	1351	1408	2759	1.18
Standing	611	684	1259	4.12*
Sitting	740	724	1464	0.18
Height of Reaches Regarded as Comfortable (Greater than 20 and less than 59 in. from floor)				
Total	1907	2030	3937	3.84*
Standing	873	1034	1907	13.59***
Sitting	1034	996	2030	0.71
Height of Reaches Regarded as Uncomfortable (Greater than 59 and less than 20 in. from floor)				
Total	131	190	320	10.84***
Standing	55	102	157	14.07***
Sitting	76	88	164	0.88
(Greater than 49 and less than 30 in. from floor)				
Total	687	812	1499	10.42**
Standing	317	412	729	12.38***
Sitting	370	400	770	1.17
(Greater than 49 in.)				
Total	357	495	852	22.35***
Standing	159	249	408	19.85***
Sitting	198	246	444	5.19*

*$P < 0.05$

**$P < 0.01$

***$P < 0.001$.

All of the different ranges of heights of reaches regarded as comfortable or uncomfortable also were tested. In each test, the hypotheses were rejected, with the larger number of reaches occurring in Location 2.

These data indicate that Location 1 would be the better arrangement, and standing to be the better position.

Angles of the Body

To obtain data for angles of body bend, the subject was posed at the various areas and centers of the kitchen in sitting and standing positions. Single frames were exposed as the subject responded to commands of "reach" and "return." The single frames were projected upon white paper for tracing the outlines of the figure and making anthropometric marks.

The subject was instructed to reach to certain points where she was comfortable, and to indicate reaches that were slightly uncomfortable and very uncomfortable. In those extreme reaches it was noted that her body no longer maintained a right angle profile to the camera. The bend and stretch started at the knees and progressed through the hips, waist, and shoulder areas. Since the torso was twisted, it was very difficult to obtain accurate body angles. Consequently, these drawings and data have been omitted from the plates and discussion.

Data are presented showing the effect of angles of body bend as the subject reached to certain levels, both standing and sitting. The normal or control postures and the upper reaches were performed on the counter side of the kitchen with the down reaches being performed at the storage wall (Table 18).

Table 18.--Average angles of body bends when reaching at certain levels while standing and sitting.

Position	Height Reached in Inches		Angle of Body in Degrees	
	One Hand	Two Hands	One Hand	Two Hands
Standing				
Counter	37	37	160	160
Reach back 24 inches	37	37	151	148
Reach up (comfortable)	61	59	155	160
Reach up (uncomfortable)	70	66	158	158
Reach down (comfortable)	25	26	109	110
Reach down (uncomfortable)	17	17	61	63
Reach down (very uncomfortable)	10	10	59	60
Sitting				
Counter	37	37	81	81
Reach back 24 inches	37	37	74	75
Reach up (comfortable)	59	59	83	82
Reach up (uncomfortable)	66	64	86	78
Reach down (comfortable)	31	31	66	71
Reach down (uncomfortable)	21	23	48	45

These data are illustrated in Plates X through XIII, showing the changes in the postural attitude of the subject as she reached to various heights. These plates show that as the arms are stretched upward, there is considerable movement of the shoulder, and the torso rotates up to provide the stretch needed. There was more rotation of the torso noticeable when the subject reached with one hand than with both hands.

This rotation of the torso was evident whether the subject was seated or standing. For the upward reaches while seated, the subject also showed a tendency to slide forward on the chair seat, thus decreasing the angle of the knees.

EXPLANATION OF PLATE X

Changes in postural attitude of standing subject facing a work counter, as she reaches within and to the extremes of her space envelope with one hand. The angles behind the figures indicate the angle of the body.

Fig. A. Normal comfortable position, hands at the front of the counter.

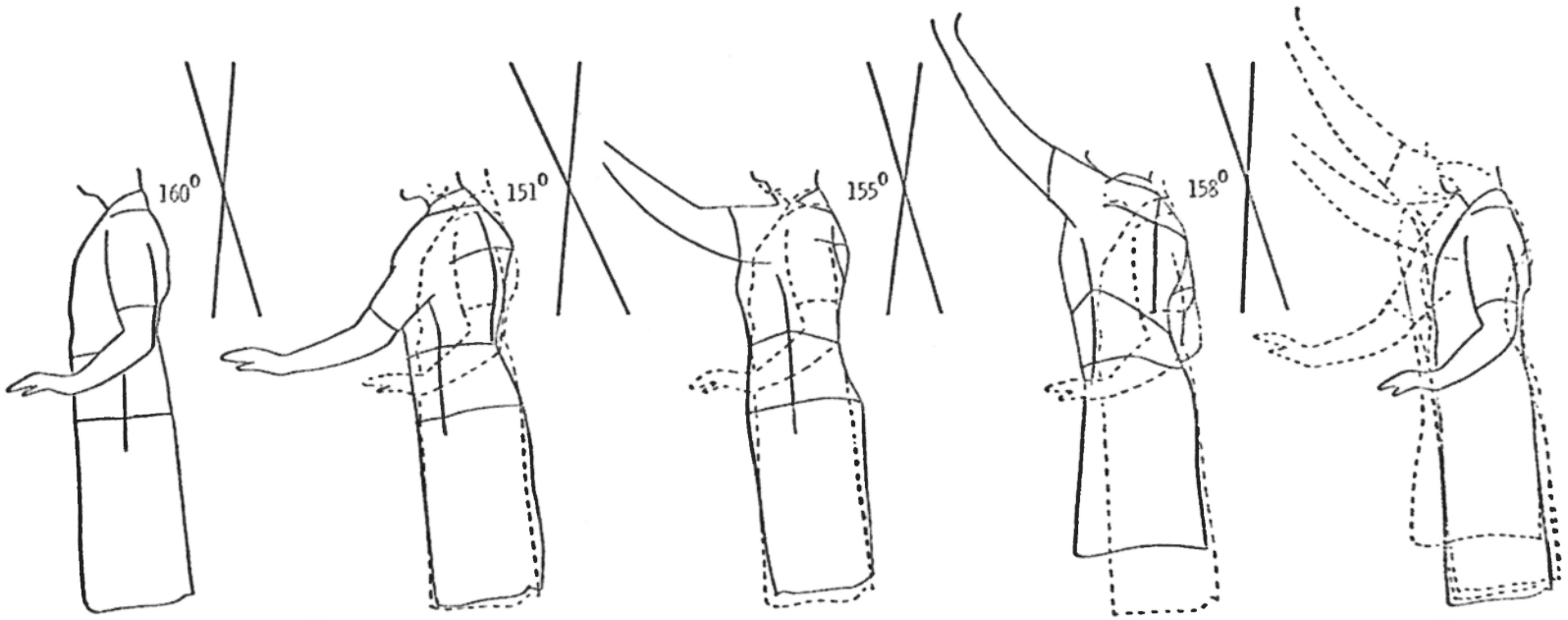
Fig. B. Reach to the back of the counter, superimposed on the normal.

Fig. C. Reach up to 61 inches, superimposed on the normal.

Fig. D. Reach up to 70 inches, the extremes of the space envelope, superimposed on the normal.

Fig. E. A composite of the above figures, indicating the range of the space envelope.

PLATE X



EXPLANATION OF PLATE XI

Description of changes in postural attitude of standing subject facing a work counter, as she reaches within and to the extremes of her space envelope with both hands. The angles behind the figures indicate the angle of the body.

Fig. A. Normal comfortable position, hands at the front of the counter.

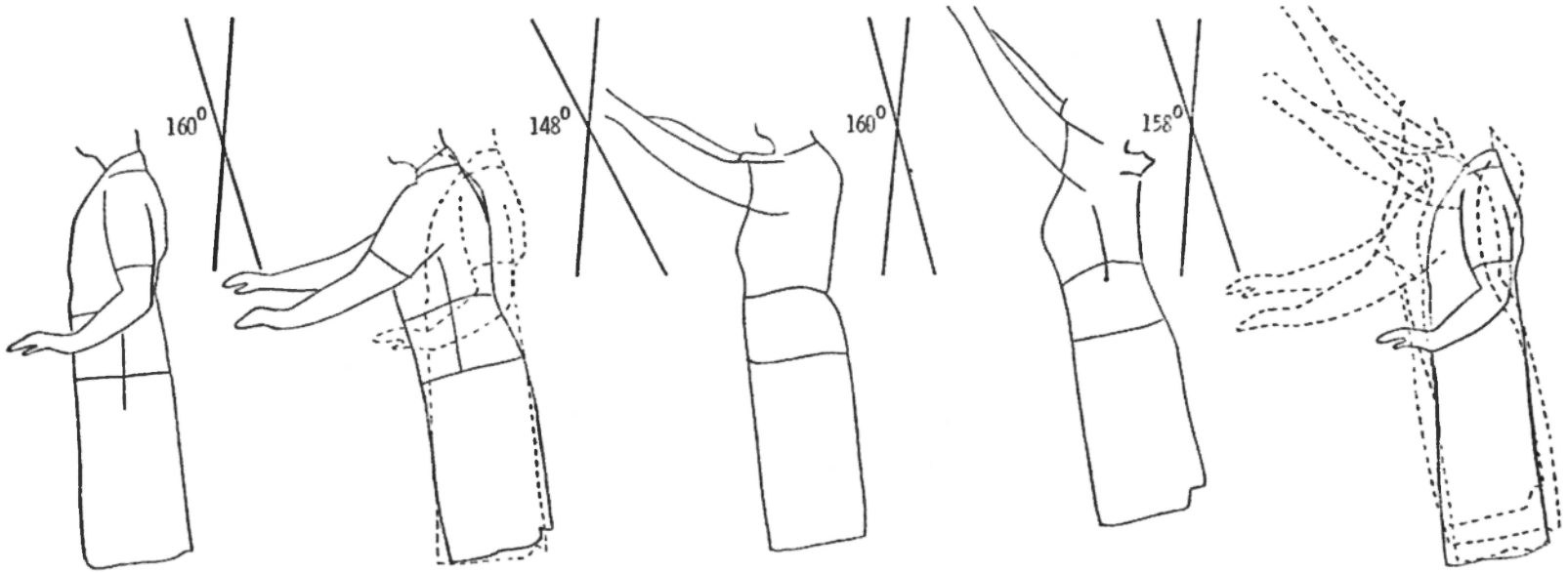
Fig. B. Reach to the back of the counter, superimposed on the normal.

Fig. C. Reach up to 59 inches, superimposed on the normal.

Fig. D. Reach up to 66 inches, the extremes of the space envelope, superimposed on the normal.

Fig. E. A composite of the above figures, indicating the range of the space envelope.

PLATE XI



EXPLANATION OF PLATE XII

Changes in the postural attitude of the seated subject facing a work counter, as she reaches within and to the extremes of the space envelope with one hand. The angles behind the figures indicate the angle of the body.

Fig. A. Normal comfortable position with hands at the front of the counter.

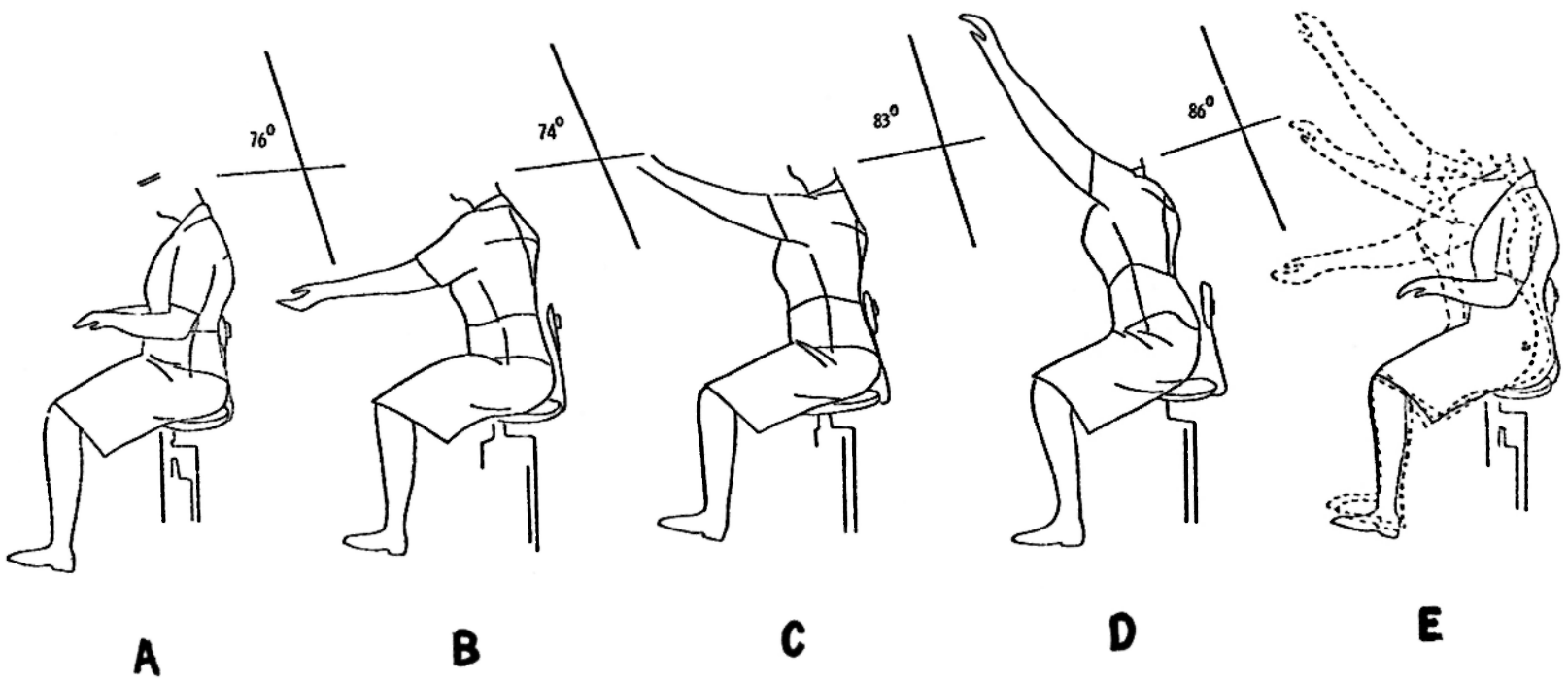
Fig. B. Reach to the back of the counter, superimposed on the normal.

Fig. C. Reach up to 59 inches, comfortable, superimposed on the normal.

Fig. D. Reach up to 66 inches, the extremes of the space envelope, superimposed on the normal.

Fig. E. A composite of the above figures, indicating the range of the space envelope.

PLATE XII



EXPLANATION OF PLATE XIII

Changes in the postural attitude of the seated subject facing a work counter, as she reaches within and to the extremes of her space envelope with two hands. The angles behind the figures indicate the angle of the body.

Fig. A. Normal comfortable position, hands at the front of the counter.

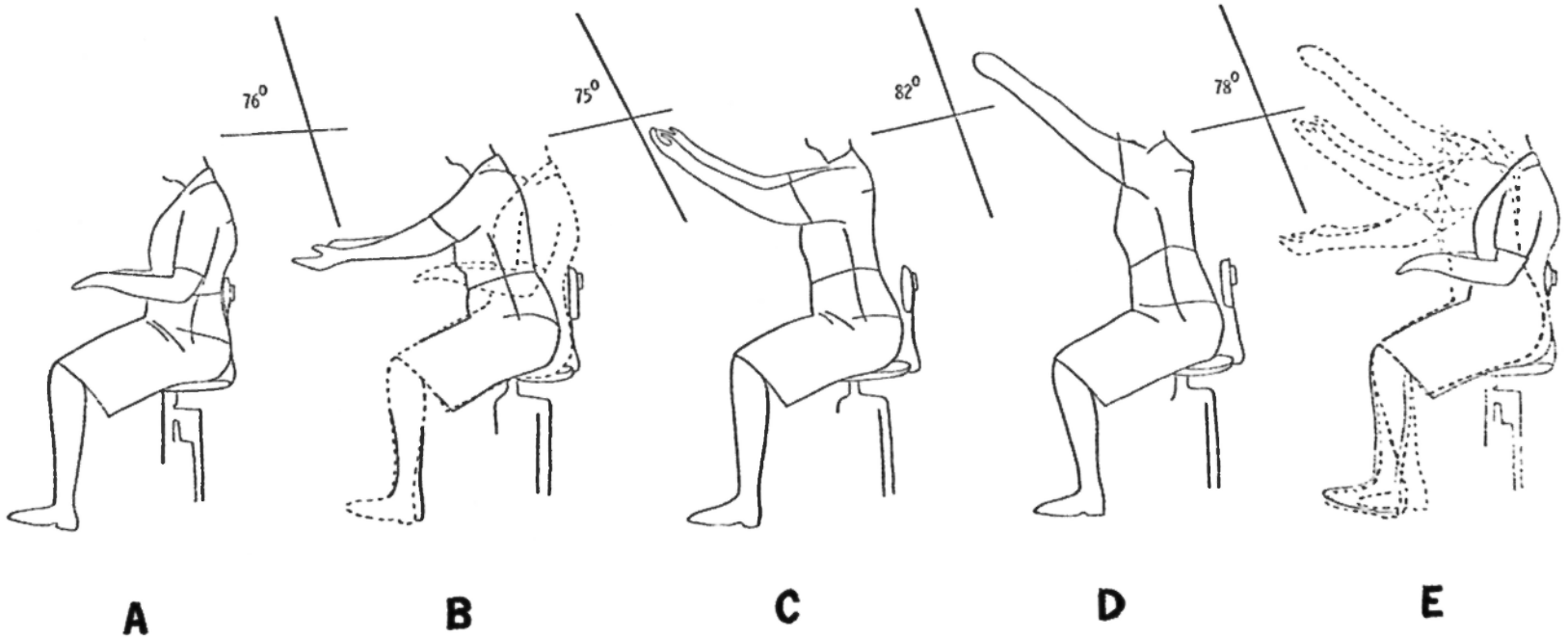
Fig. B. Reach to the back, superimposed on the normal.

Fig. C. Reach up to 59 inches, comfortable, superimposed on the normal.

Fig. D. Reach up to 64 inches, the extremes of the space envelope, superimposed on the normal.

Fig. E. A composite of the above figures, indicating the range of the space envelope.

PLATE XIII



Plates XIV through XVI show front and back views of the subject as she reaches up and down. These drawings are the result of the subject being instructed to face the counter wall, then to swing around to reach an item in the storage wall. The use of the whole body is evident in making the reaches.

EXPLANATION OF PLATE XIV

Changes in the postural attitude of the standing subject as she bends and reaches within the space envelope and to the extremes with both hands. The angles behind the figures indicate the angle of the body.

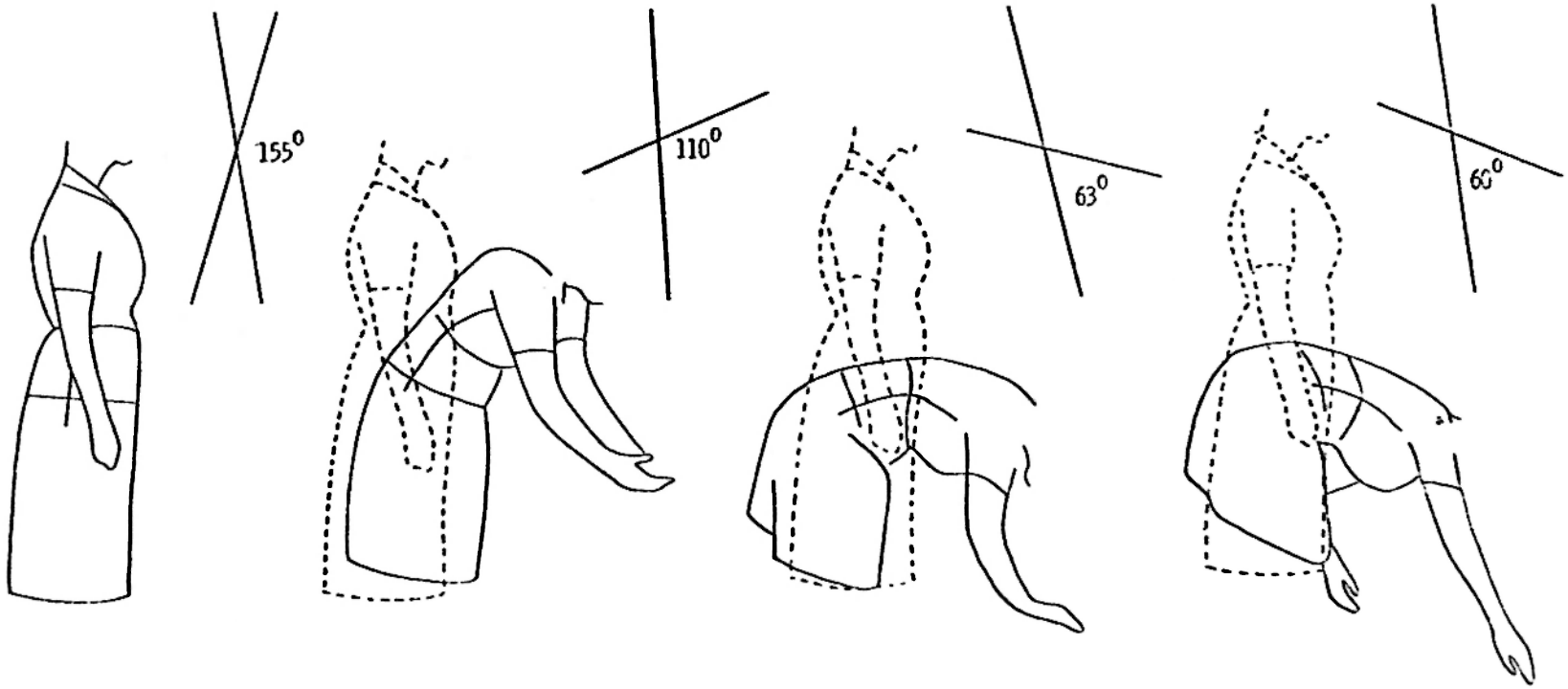
Fig. A. Standing in a normal comfortable position.

Fig. B. Reaching down to 26 inches above the floor, superimposed on the normal.

Fig. C. Reaching down to 17 inches above the floor, superimposed on the normal.

Fig. D. Reaching down to 10 inches above the floor, superimposed on the normal.

PLATE XIV



EXPLANATION OF PLATE XV

Changes in the postural attitude of the seated subject as she works between the counter and the storage wall, front and back views.

Fig. A. Reaches between counter and pulls out shelf on storage wall.

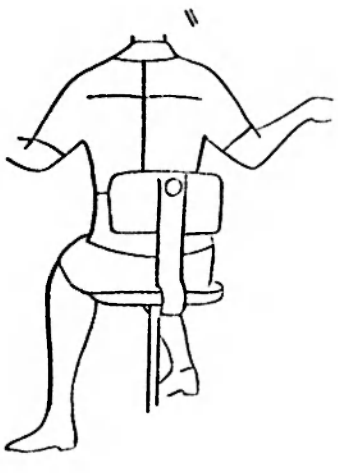
Fig. B. Reaches a pan, turning from counter to storage wall.

Fig. C. Reaches to wastepaper basket from counter to storage wall.

Fig. D. Reaches salad bowl from counter to storage wall.

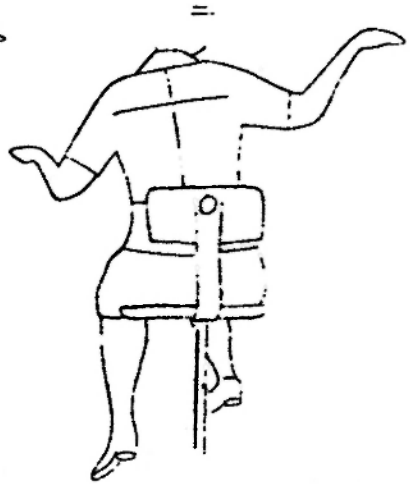
PLATE XV

A FRONT



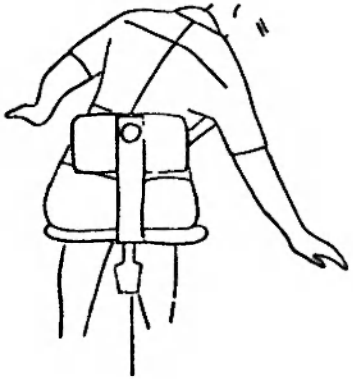
A BACK

B FRONT



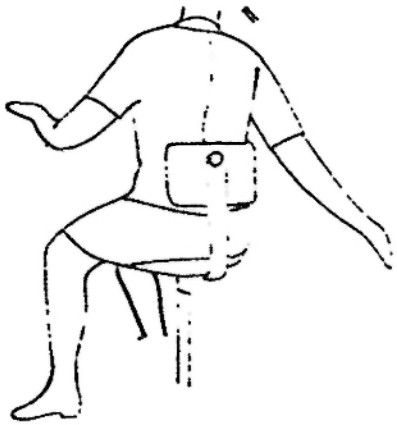
B BACK

C FRONT



C BACK

D FRONT



D BACK

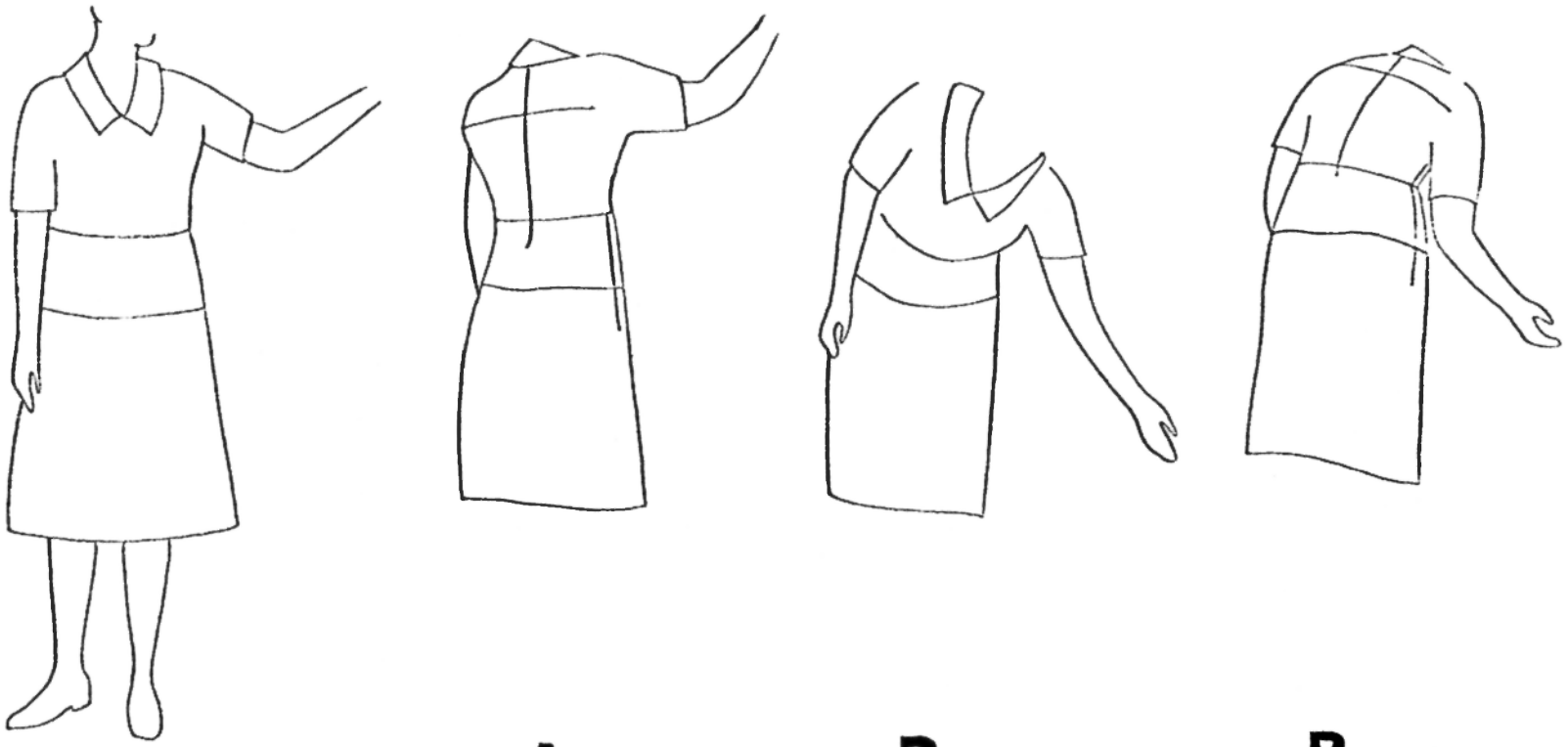
EXPLANATION OF PLATE XVI

Changes in the postural attitude of standing subject as she works between counter and storage wall.

Fig. A. Reaching up.

Fig. B. Reaching down.

PLATE XVI



A FRONT

A BACK

B FRONT

B BACK

SUMMARY AND CONCLUSIONS

This research project consisted of designing and evaluating a kitchen arrangement for a person not wheel-chair bound, but who must be or who desires to be off her feet for any reason. A motor-driven chair, operating on a track under the counter, was designed for her to sit to work. The counter and storage wall opposite were organized into centers, and items normally related to the centers and to the normal comfortable reach of a woman were so located or stored.

The sink and preparation areas were near the center of the counter. Preliminary trials eliminated all but two possible locations for the cook-top. The arrangement designated as Location 1 progressed from left to right from the North End counter to Sink Center, Preparation Center, and Cook-top Center, and Location 2 progressed from Cook-top Center, Sink Center, Preparation Center, and South End counter.

The objectives of this study were to determine the better location of the cook-top unit, using motion, time, reaches, and body angles as criteria, and to determine whether the motorized chair made a significant difference in the amount of time, travel, and reaches.

The experimental design included proper methods of procedure and standard measurements. It was limited by the use of one subject, whose stature was within the bell-shaped normal curve of distribution of dimensions for women. Lack of funds made other compromises necessary. Within these limitations the results are presented.

The standard method of testing kitchens, namely, preparation of food for typical menus was used. Two techniques for measuring included: trip charts, involving time and distance, and memomotion movie films, analyzed for time and motion, and for the illustrations of the body positions used. Tests were made with the subject both standing to work and seated in the motorized chair.

Trip chart data indicated that the location of the cook-top made no significant difference in the amount of total time required in the preparation of the menus. This was substantiated by memomotion analysis. Travel time was affected, however, by the location of the cook-top if the menu was simple, but not if the menu was complicated. In this case, Location 1 was favored.

Sitting to prepare the menus took longer than standing. This might be partially accounted for by the speed of 2 miles per hour for the chair as against an estimated 2.5 miles per hour for walking.

The distance traveled was related to the location of the cook-top, with the advantage for Location 1. Standing to work required a greater distance traveled than sitting to work. When standing, she walked not only along the front of the counter but also toward the storage wall. Also some of the distance walked included shifts of position of the feet from side to side and forward or backward. Distance traveled in the chair may have been less because to reach the storage wall, she

merely turned the chair which brought her nearer the storage wall. Other factors may have been that she had a tendency to stretch her body to reach into adjoining centers rather than moving the chair a few inches. As she gained skill in operating the chair, this tendency was less.

Use of Centers

More time spent in an area concentrated the work, and a greater number of trips to it in effect dispersed the efforts of the worker and increased the distance traveled. More time was spent in the preparation area when the cook-top was in Location 1 than when in Location 2, and also when the subject was sitting than when she was standing. The number of trips to the areas was less when the cook-top was in Location 1 than when in Location 2. When seated, the areas were used equally. When standing, more trips were made to the areas with the cook-top in Location 2.

The preparation area was the most important for performing manipulations, regardless of the location of the cook-top or whether the subject was standing or sitting. More time was spent in manipulation in any of the areas when the cook-top was in Location 1 and when the subject was standing, but not when sitting.

Body Positions

Changes in body stance, as shown by postural attitude, have been found to be associated with changes in energy consumption,

although no correlation is suggested here. A description of postural attitude when reaching up, down, and forward within the reach envelope is presented. Also, the number and height of reaches are enumerated.

The height the subject could reach and the rotation of the torso varied with whether the subject was reaching with one or two hands. Observation showed that the bend and stretch started at the knees and progressed through the hips, waist, shoulders, and arms. Rotation of the torso was evident whether the subject was seated or standing.

One of the criteria of a good kitchen arrangement for work economy and body mechanics is a minimum number of reaches. Location 1 and standing produced the least number of reaches. Between 91% and 94% of the reaches occurred in the comfortable and fairly comfortable zone of 20 to 59 inches above the floor.

From practically all of the tests conducted on this kitchen, Location 1 with its progression of areas from North End Counter, Sink Center, Preparation Center to Cook-top Center proved to be the better with the exception of the amount of time required which was not significantly different from Location 2. Storage of the items in the centers was within easy reach since only 6.4% of <u>all</u> the reaches were in the uncomfortable range of below 20 inches and above 59 inches.

The proposed kitchen design appears to be a compact, workable arrangement enabling meal preparation both sitting and standing. Although sitting appeared to take longer than

standing, women would be encouraged to sit because the centers are well organized, the chair operates easily, and the need for getting on and off, common to other sit-stand arrangements, is eliminated.

The implications of this research would appear to be that this basic design, or variations of it, could enable a homemaker to be off her feet while preparing meals. It is recognized that certain adjustments for homemakers with specific limitation would be required, usually with recommendations from the physician or physical therapist.

The basis for the arrangements in this kitchen was the result of research done by home economists on principles of work economy, the normal reach of women in a work center, and the amount of energy used as measured by calorimetry. More recent techniques such as measurements of heart beat and force, used by industry and in the space program, would appear to offer easier information. Heart beats and measurements of force used for the various activities are presently unknown. But their use may replace or substantiate known limits established by calorimetry and may provide a better basis for recommendations for performance of work and for the design of equipment and work places.

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APPENDICES

APPENDIX A

MENUS USED

Menu A

Broiled Hamburgers and Potato Slices
Glazed Carrots
Relish Plate
Bread and Butter
Bisquick Shortcake with Frozen Fruit
Coffee and Milk

Menu B

Cheese Fritters
Green Beans with Bouillon
Cabbage, Carrot Salad with Prepared Dressing
"Whip and Chill" Pudding and Cookie Dessert
Coffee and Milk

Menu C

Hamburger Pizza
Green Goddess Salad with Special Dressing
Glamorous Fruit Cup
Coffee and Milk

APPENDIX B

RANDOM ORDER OF PREPARATION FOR MENUS AND INDIVIDUAL FOODS

Menus: Location 1	Menus: Location 2
1) Sitting - Menu C	1) Standing - Menu B
2) Sitting - Menu B	2) Standing - Menu B
3) Standing - Menu B	3) Standing - Menu A
4) Standing - Menu A	4) Sitting - Menu C
5) Standing - Menu C	5) Sitting - Menu A
6) Sitting - Menu A	6) Sitting - Menu A
7) Sitting - Menu A	7) Standing - Menu C
8) Sitting - Menu C	8) Sitting - Menu C
9) Sitting - Menu B	9) Standing - Menu A
10) Standing - Menu A	10) Sitting - Menu B
11) Standing - Menu C	11) Standing - Menu C
12) Standing - Menu B	12) Sitting - Menu B

Individual Foods: Location 1

1) Sitting - Green Beans with Bouillon
2) Standing - Cheese Fritters
3) Sitting - Green Goddess Salad with Dressing
4) Sitting - Coffee
5) Standing - Hamburger Pizza
6) Standing - Green Goddess Salad with Dressing
7) Standing - Green Beans with Bouillon
8) Sitting - Whip & Chill Cookie Dessert
9) Standing - Coffee
10) Standing - Coffee
11) Sitting - Green Goddess Salad with Dressing
12) Standing - Glazed Carrots
13) Sitting - Coffee
14) Standing - Cheese Fritters
15) Standing - Glazed Carrots
16) Sitting - Glazed Carrots
17) Sitting - Cheese Fritters
18) Sitting - Bisquick Shortcake with Frozen Fruit
19) Standing - Hamburger Pizza
20) Sitting - Glazed Carrots
21) Sitting - Cheese Fritters
22) Sitting - Whip and Chill
23) Standing - Fruit Cup
24) Standing - Broiled Hamburger and Potato
25) Standing - Broiled Hamburger and Potato
26) Standing - Cabbage, Carrot Salad & Prepared Dressing
27) Sitting - Bisquick Shortcake with Berries
28) Standing - Green Goddess Salad
29) Standing - Bisquick Shortcake with Berries
30) Sitting - Cabbage, Carrot Salad with Prepared Dressing
31) Sitting - Cabbage, Carrot Salad with Prepared Dressing
32) Sitting - Broiled Hamburger and Potato Slices
33) Sitting - Hamburger Pizza
34) Standing - Green Beans with Bouillon
35) Standing - Cabbage Carrot Salad with Prepared Dressing
36) Sitting - Glamorous Fruit Cup
37) Sitting - Green Beans with Bouillon
38) Standing - Bisquick Shortcake with Frozen Fruit
39) Standing - Whip & Chill and Cookie Dessert
40) Sitting - Hamburger Pizza
41) Sitting - Glamorous Fruit Cup
42) Sitting - Broiled Hamburger and Potato Slices
43) Standing - Whip & Chill and Cookie Dessert
44) Standing - Glamorous Fruit Cup

Individual Foods: Location 2

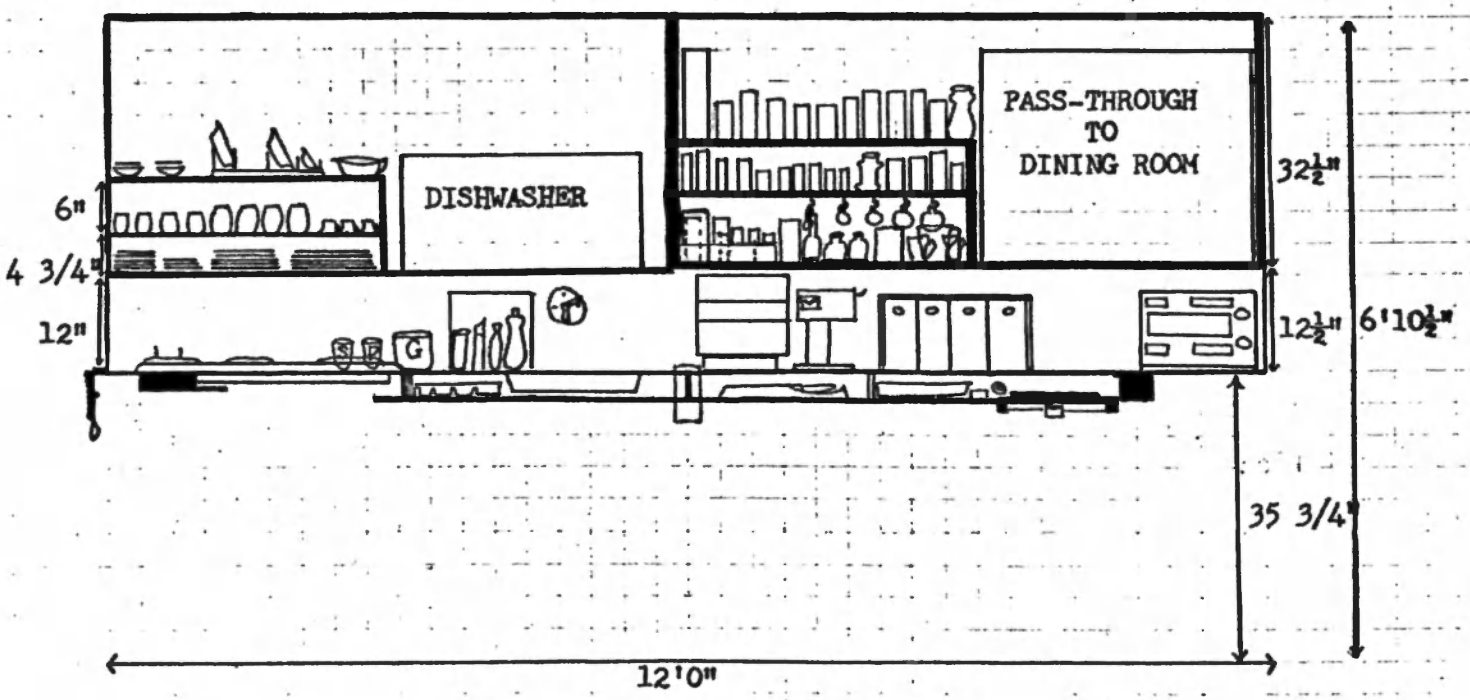
1) Standing - Whip & Chill and Cookie Dessert
2) Standing - Green Beans with Bouillon
3) Standing - Cabbage, Carrot Salad with Prepared Dressing
4) Sitting - Glamorous Fruit Cup
5) Standing - Bisquick Shortcake with Frozen Fruit
6) Sitting - Broiled Hamburger and Potato Slices
7) Sitting - Glazed Carrots
8) Sitting - Cabbage, Carrot Salad with Prepared Dressing
9) Sitting - Glamorous Fruit Cup
10) Standing - Broiled Hamburgers and Potato Slices
11) Standing - Glamorous Fruit Cup
12) Sitting - Hamburger Pizza
13) Standing - Green Goddess Salad with Dressing
14) Standing - Green Goddess Salad with Dressing
15) Sitting - Cheese Fritters
16) Standing - Whip & Chill and Cookie Dessert
17) Standing - Coffee
18) Standing - Hamburger Pizza
19) Sitting - Bisquick Shortcake with Frozen Fruit
20) Sitting - Pizza Hamburger
21) Standing - Broiled Hamburgers and Potato Slices
22) Standing - Cheese Fritters
23) Standing - Glamorous Fruit Cup
24) Standing - Coffee
25) Sitting - Cheese Fritters
26) Standing - Bisquick Shortcake with Frozen Fruit
27) Sitting - Green Beans with Bouillon
28) Sitting - Cabbage, Carrot Salad with Prepared Dressing
29) Standing - Cabbage, Carrot Salad with Prepared Dressing
30) Standing - Hamburger Pizza
31) Sitting - Green Goddess Salad with Dressing
32) Sitting - Whip & Chill and Cookie Dessert
33) Sitting - Whip & Chill and Cookie Dessert
34) Sitting - Green Goddess Salad with Dressing
35) Sitting - Glazed Carrots
36) Sitting - Broiled Hamburgers and Potato Slices
37) Standing - Cheese Fritters
38) Sitting - Green Beans with Bouillon
39) Sitting - Bisquick Shortcake with Frozen Fruit
40) Standing - Green Beans with Bouillon
41) Sitting - Coffee
42) Sitting - Coffee
43) Standing - Glazed Carrots
44) Standing - Glazed Carrots

APPENDIX C

EXPLANATION OF PLATE XVII

Drawing of counter (east) wall of experimental kitchen with the motorized chair.

PLATE XVII

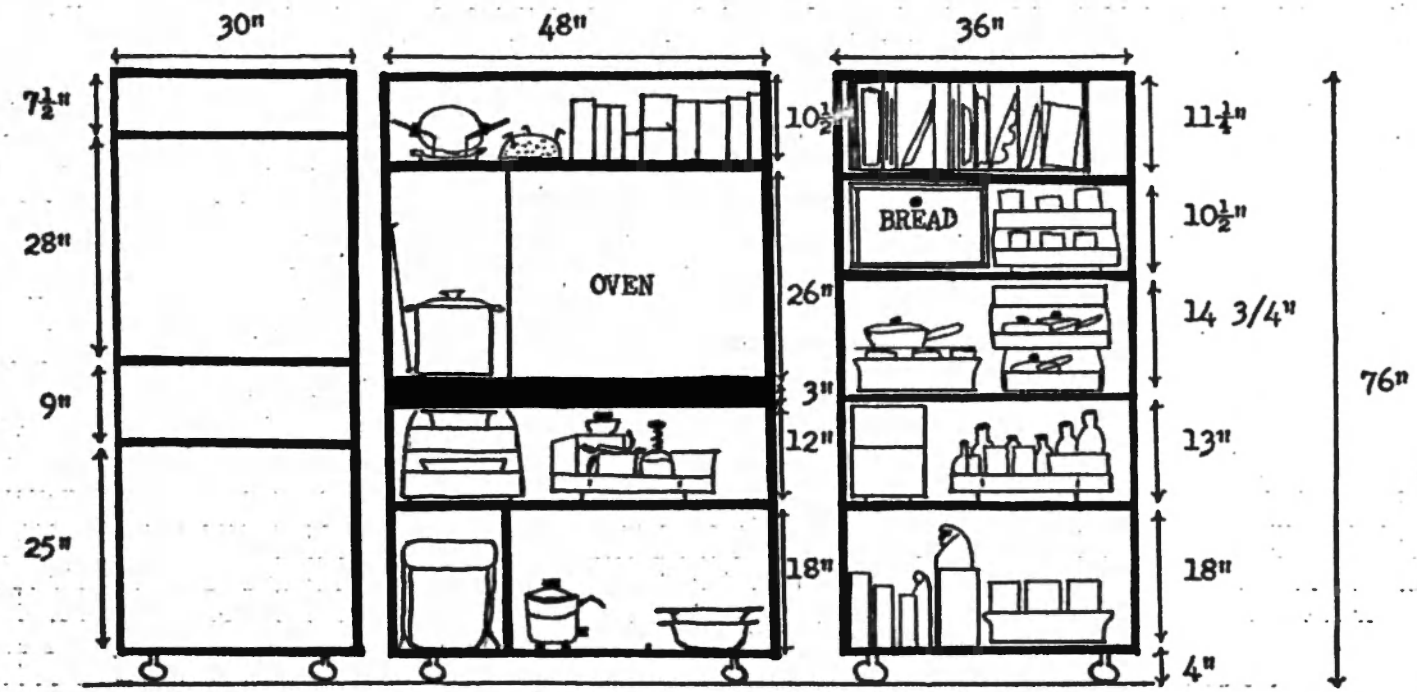


RESEARCH KITCHEN
SCALE: ½" = 1'

EXPLANATION OF PLATE XVIII

Drawing of storage (west) wall of experimental kitchen.

PLATE XVIII



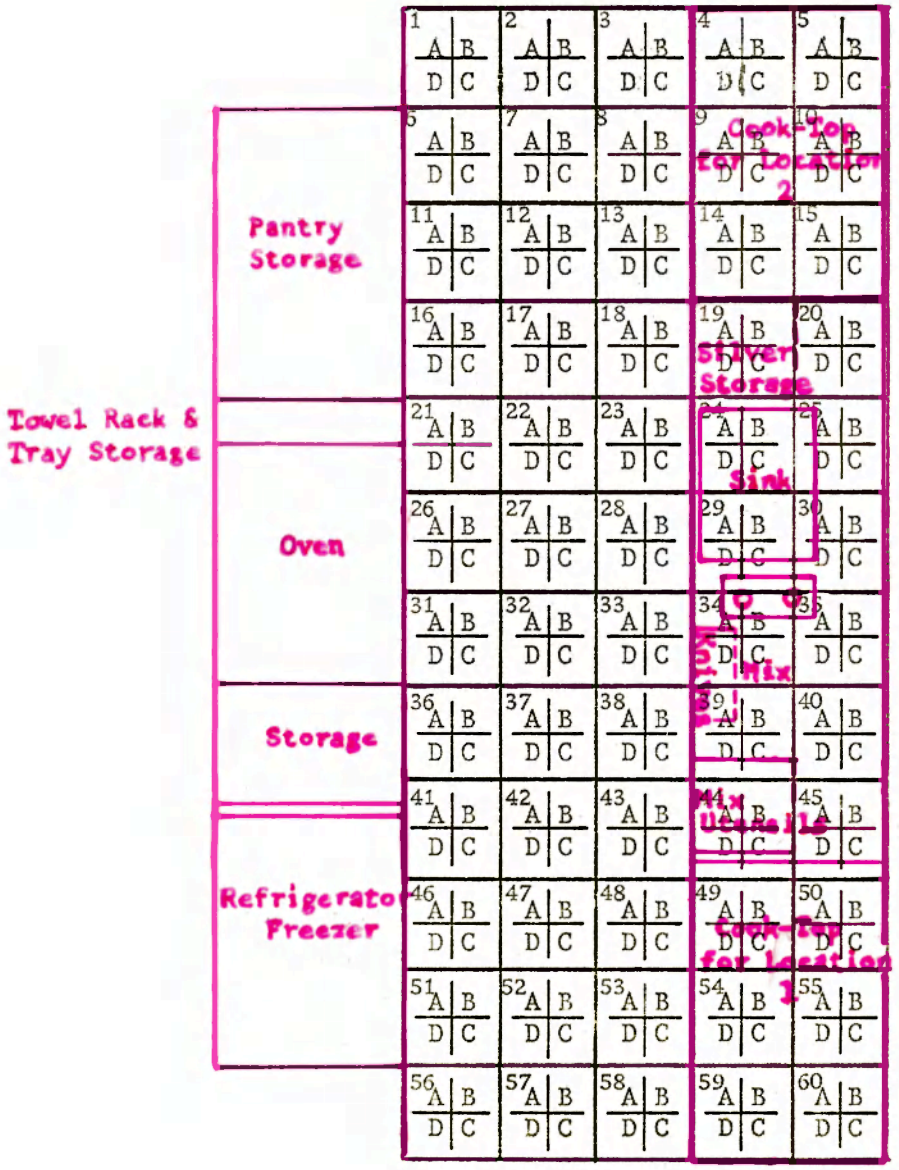
STORAGE WALL
SCALE: ½" = 1'

EXPLANATION OF PLATE XIX

Drawing showing the floor markings used in trip charting process.

N

PLATE XIX



Scale: ½ inch = 1 foot

APPENDIX D

PROCEDURES FOR TAKING ANTHROPOMETRIC MEASUREMENTS

The following procedures were established for measurements taken of the subject.

Four measuring devices were used. A Decto Scale with a capacity of 300 pounds was used for taking weight. An anthropometer was used to measure heights. Sliding calipers were used to measure depths and widths. A standard tape measure was used to measure lengths.

Anthropometric markings, dots on masking tape, were placed on the acromion, greatest hip protuberance, greater trochanter, and waist line.

For the weight, the subject was asked to stand quietly on both feet without shifting her weight at the center of the weighing platform.

STANDING HEIGHTS

A. Stature

The subject stood in front of the anthropometer with her back toward it, arms by her sides, weight evenly distributed, with feet as close together as comfortable. She moved backward slowly until some part of her body touched the upright scale of the anthropometer.

The left hand of the measurer located the vertex of the head of the subject. The crossbar of the anthropometer was lowered until it rested on the vertex of the subject's head.

The crossbar was set at the point, and the measurement read.

B. Shoulder Height - Standing

The subject stood erect, feet as close together as comfortable, with her right side facing the anthropometer. Her eyes were directed forward, and arms to the side. The measurer stood to the back and slightly to the right of the subject.

The crossbar of the anthropometer was lowered to the acromion, set, and the measurement read. This procedure was repeated for the left shoulder.

C. Elbow

The subject stood as for the previous measurement, and at a distance from the anthropometer so that the crossbar could be lowered to show the elbow height.

The measurer stood to the back and right of the subject. The subject bent her arm so that a right angle was formed by the upper arm hanging straight and the forearm parallel to the floor. The crossbar was moved to the elbow level and the measurer sighted to see that the under edge of the elbow was parallel with the crossbar. The crossbar was set and the measurement read.

D. Waist

The waist level was located at the lower edge of the lowest rib and was found by palpating the sides of the body at the midaxillary line.

To locate it, the measurer sat in front of the subject and palpated the right and left sides simultaneously, using the index

fingers to press against the sides in line with the arm pits. The hands were held with the palms directed toward the floor and the fingers extended and together. The thumb-side of the middle joint of the index finger was placed against the subject. When the lower edge of the lowest rib was felt on the back surface of the index finger, the level of the mid-line of the index finger was taken at the waist level. Without distorting the contour of the flesh, the level was marked with a dot in line with the arm pit on the right and left sides in turn.

The subject stood erect with her side toward the anthropometer crossbar. Her arms hung loosely at the sides. The crossbar was lowered until it rested on the landmark, and the reading taken. The procedure was repeated for the other side.

E. Hip

The level was determined separately for the right and left sides.

The extended index and middle fingers of the measurer's right hand were used to palpate the region of the trochanter. To locate the proper level the subject may have bent slightly forward, or rotated the femur by turning the toes laterally or by pivoting on the heel. A rounded depressed region, known as the bench, the midpoint of which was the hip level, was marked.

The subject stood erect with her side to the anthropometer, her hands close together at the front, and her weight evenly distributed.

The measurer knelt to the right of the subject, keeping her eye on a level with the landmark. The crossbar was lowered to rest on the body mark, and the reading taken. The procedure was repeated for the left side.

F. Knee Height (Tibiale)

The tibiale was taken as the highest point on the margin of the glenoid (hollowed like a shallow pit) of the tibia when the subject stood erect. The medial "cleft" of articulation between the condyles (an enlarged and prominent end of a bone) of the femur and the upper end of the tibia was used as a guide in locating this.

The subject stood in front of the crossbar facing the anthropometer. The measurer squatted at the subject's right side with her eyes at the knee level. The crossbar was brought to rest on the body mark, and the reading taken.

G. Height of Finger Tip (Dactylion)

The subject stood with her right side facing the anthropometer. The arms hung loosely at the side with the fingers straight but not rigid. The measurer positioned herself to the back and right of the subject, squatting to bring her eye level to the finger tip. The crossbar was leveled to the finger tip, and the measurement taken.

H. Eye Level

The subject stood with her left side facing the anthropometer. The arms hung loosely at the side. The measurer positioned herself to the front and left of the subject. The

crossbar was leveled to the mid-point of the eye, and the measurement taken.

ARM LENGTH MEASUREMENTS

A. Shoulder to Elbow

The subject stood with normal, erect posture, feet together. She bent her right arm, keeping the wrist straight; her clenched fist was placed on her hip with the back of the hand to the front.

The measurer stood at the right side of the subject and slightly to the back. The tape measure was placed on the acromion process of the scapula, and the measurement taken to the tip of the elbow.

B. Elbow to Palm

The subject stood with normal erect posture, feet together. The measurer stood to the right of the subject. With the upper arm hanging downward naturally, a right angle was made with the forearm. The tape measure was extended from the tip of the elbow to the knuckle of the little finger.

WIDTH MEASUREMENTS

A. Greatest Width at Shoulders

The subject stood erect, feet together as closely as comfortable; arms were at the side, and palms on the thighs.

The measurer stood directly behind the subject. The caliper was held parallel to the floor and touching the back of the subject at shoulder height. The fixed bar of the caliper was placed against the left arm of the subject at the greatest

extension, not more than one inch below the highest point of the shoulder cap. The movable bar was slid against the right upper arm of the subject at its greatest extension.

B. Greatest Width Arms Bent

The subject stood erect, feet together comfortably. She held a tray bearing a weight of 8 to 10 pounds as she would normally carry it (about waist height).

The measurer stood behind the subject and held the caliper shaft parallel to the floor. The fixed bar was held against the outside of the left elbow, and the movable bar was slid against the outside of the right elbow.

C. Greatest Width Below 36 Inches

The subject stood erect with weight evenly distributed, eyes directed straight ahead, and hands clasped at the waist.

The measurer stood directly behind the subject and held the shaft of the caliper parallel and level with the floor. The fixed bar and the movable bar were fitted on either side of the subject at the waist. The caliper was expanded as needed and lowered until the greatest extension below 36 inches was located.

D. Sitting Length

The subject sat erect on a chair adjusted so the edge of the seat just touched under the knees. The back of the chair fitted at the small of the back. The feet were flat on the floor and the hands were held in the lap.

The measurer stood at the side of the subject and held the shaft of the caliper parallel to the floor, with the fixed bar

at the front of the knee. The movable bar was touched against the buttocks.

DEPTH MEASUREMENTS

A. Bust

The subject stood erect, weight evenly distributed over both feet, feet comfortably close together, eyes straight ahead, and hands hanging at the side.

The measurer stood at the right side of the subject facing her. The shaft of the caliper was held level and parallel to the floor while the fixed bar was placed at bust height on the back of the subject. The movable bar was then positioned at the furthest extension of the bust in front.

B. Abdomen Standing

The subject stood erect, with feet as close together as comfortable, with weight evenly distributed over both, eyes straight ahead and hands hanging at the side. The measurer stood at the right side of the subject, facing her. The shaft of the caliper was held level and parallel to the floor while the fixed bar was at the rear. The movable bar was at the front and the whole was moved up and down until the greatest thickness was found.

SITTING HEIGHTS

A. Stature

The subject sat erect on a stool with her back to the anthropometer, hands in her lap and both feet on the floor.

The measurer stood at the left side of the subject. The crossbar was lowered to rest on the vertex of the subject's head.

B. Shoulder

The subject sat erect on a stool with her right side facing the anthropometer, hands in her lap.

The measurer stood at the right side and back of the subject. The crossbar was lowered to rest on the acromion process of the scapula. The process was repeated for the left shoulder.

C. Elbow.

The subject sat erect on a stool with her right side facing the anthropometer.

The measurer stood to the back and the right of the subject. The subject made a right angle of the arm,with the upper arm hanging straight and the forearm parallel to the floor. The crossbar of the anthropometer was lowered to the level of the elbow, touching the arm slightly.

D. Waist

The subject sat erect on a stool at a right angle to the crossbar. Arms were in the lap and slightly forward to permit clear view of the waist body mark.

The measurer stood at the right and slightly back of the subject. The crossbar was lowered until it was in line with the body mark. The process was repeated for the left side.

E. Hip

The subject sat erect on a stool at a right angle to the crossbar of the anthropometer. Hands were in the lap.

The measurer stood to the right and slightly back of the subject. The crossbar was lowered until the tip rested on the hip body mark. The process was repeated for the left side.

F. Height of Top of the Thigh

The subject sat erect on a stool at right angles to the crossbar of the anthropometer, knees snug against the edge, hands clasped at the waist.

The measurer stood in front of the subject. The crossbar was raised and then lowered to the thigh, and the subject moved forward until the greatest thickness of the thigh was found.

G. Top of the Knee

The subject sat on a stool, knees snug against the edge of the crossbar of the anthropometer, hands clasped at the waist.

The measurer stood in front of the subject. The crossbar was lowered to the top of the knee just where the knee bends.

H. Eye Level

The subject sat erect on a stool at right angles to the anthropometer, hands in her lap.

The measurer stood to the back and at one side of the subject. The crossbar was lowered to the mid-point of the eye.

The process for seated measurements was repeated, with the subject seated in the mechanical chair. The floor of the platform was used as the base or beginning of the measurements. For seated jobs, all measurements should be considered from the floor of the chair, which stands six inches above the floor of the platform on which the kitchen was built.

APPENDIX E

Measurements of the Subject

Age	55 years
Weight	141 pounds
Body Build Index	2.2
Standing	**Inches**
Stature	64
Shoulder	52 1/2
Elbow	40 1/16
Waist	40 1/16
Hip	33 6/8
Fingertip	25 7/8
Knee	18 1/8
Eye level	54 7/8
Greatest width	
shoulder	14 3/4
arms bent	18 1/4
below 36"	14 3/4
Depth of bust	9 1/4
Depth of abdomen	10 1/4
Sitting	
Vertex of head	50 7/8
Shoulder	39 1/4
Elbow	26 5/8
Waist	27 1/4
Hip	22
Height, top of thigh	23
Height, top of knee	20 1/4
Widest extension, hips	16 1/8
Sitting length	22 3/4
Arm Length	
Shoulder to elbow	13
Elbow to palm	11 1/4

Subject's Sitting Measurements in Mechanical Chair to Platform

Counter Height	37 1/8
Vertex of head	58 1/2
Shoulder	46 1/2
Elbow	34
Waist	34 1/2
Hip	29 3/4
Height of thigh	30 1/2
Height, top of knee	27 1/8
Chair floor to platform	6 3/8
Chair seat front	25 1/2
Chair seat back	24 7/8

APPENDIX F

Method of Determing Body Angles

I. Body Angle

1. Draw a line through ankle to point of greatest protuberance on hips. Extend this line. This is usually the hip line on the dress, unless there is obvious dislocation. Then take the point touching a perpendicular line, or when bent the most projecting point between two lines defining the bend.
2. Draw a line from the point of greatest protuberance of the hips through the point on the spectacles.
3. Measure the angle between these lines; the fulcrum being the hip protuberance.

II. Arm to Floor

1. Draw a line through the shoulder point perpendicular to the base line.
2. Draw a line from the shoulder to the elbow.
3. Measure the angle from the perpendicular line to the shoulder-to-elbow line, beginning with the perpendicular line over the head; the fulcrum being the shoulder point.

III. Arm Bend

1. Draw a line from elbow to wrist.
2. Measure the angle from shoulder to wrist; the fulcrum being the elbow.

DESIGN FOR A SIT-STAND KITCHEN UTILIZING A MOTORIZED CHAIR

by

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The purpose of this research was to design a kitchen arrangement suitable for a person standing to work and for a person seated on a motorized chair. The motorized chair, operating on a track the full length of the kitchen counter, is meant to relieve a homemaker, not wheel-chair bound, yet who must or desires to be off her feet for any reason. Its use posed problems in kitchen design because of displaced under-counter storage, and a counter served by storage appropriate for sitting-standing operations.

The focus of the study was in two stages: to establish centers on the counter with appropriate storage above them and in the storage wall, and to determine the best relationship of the centers to each other.

The working area of the two-wall kitchen, as designed, was the counter with a sink and preparation area in the middle, leaving two possible locations for the cook-top. Two types of measurements determined which location was better; trip charts including time and travel distance used, and memomotion analysis of movie films of the preparation of typical menus. The experimental design included tests of measurements of time spent in centers, number of times the centers were used, and number and height of reaches. In addition, body positions while reaching to the various parts of the work envelope or kinetosphere were graphically portrayed.

The location of the cook-top at the right of the sink and preparation areas resulted in more manipulations being done at

one time in each of the areas of the counters, fewer shifts between areas, and less travel distance. For these reasons, the right of the sink was considered a better location for the cook-top in this kitchen.

The preparation area was found to be the most important from the standpoint of amount of time spent and number of manipulations performed there.

The storage of this kitchen permitted easy postures. Of all reaches, 62% were within the zone regarded as most comfortable (between 30 and 49 inches from the floor) and over 90% were within 20 to 59 inches from the floor regarded as comfortable.

The proposed kitchen design appears to be a compact, workable arrangement, enabling meal preparation in both sitting and standing positions. Although sitting appeared to take longer than standing for meal preparation, women would be encouraged to sit because the centers are well organized, the chair operates easily, and the necessity to get on and off the chair is largely eliminated.

The implications of this research are that this basic design, with variations, could enable a homemaker needing or wanting to be off her feet to prepare meals.

The basis for the arrangements in this kitchen was the result of research done by home economists on principles of work economy, the normal reach in a work center, and the amount of energy used as measured by calorimetry. More recent techniques,

such as measurements of heart beat and force, offer more easily obtained information. Such information for the various activities is presently unknown. But their use may replace or substantiate presently recognized measurements established by calorimetry and may provide a better basis for recommendations for performance of work and for the design of equipment and work places.