SPACE REQUIREMENTS FOR QUANTITY FOOD PRODUCTION ACTIVITIES
USE OF MECHANICAL MIXER

by

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INTRODUCTION

"The human body, its structure and mechanical function occupies a central place in man-machine design." (Damon et al., 1963, p. 486). However, his efficiency, safety and comfort in the environment are factors frequently neglected. In food service operations, the relationship of the worker to preparation and cooking equipment is a vital factor in the determination of space needs. When the architect, food service planning consultant, dietitian or restaurateur plans a new unit he finds few scientifically determined space requirement standards. Most frequently the equipment manufacturer's specifications provide the basis for initial space allocations.

In such circumstances the relationship of the food service worker to his working environment is overlooked. It is not difficult to find examples of this oversight; for example, a range door opening onto a work aisle which is too narrow to accommodate the open door and the worker removing food from the oven. Expansion of the food service industry has created a dependence on mechanized equipment for many preparation and all cooking activities. For this reason the safety and comfort of food service workers in the mechanical environment assume primary importance.

Fogel (1963, p. 477) stated that the human operator is dynamic and that the task-environment-operator situation must take into account his moveability. In planning to accommodate the worker in the task-environment-operator situation the designer should aspire to attain a situation in which all workers can operate all machines. This goal is an ideal one, the attainment of which may necessitate compromises resulting in no less than 90 percent of workers being able to operate all machines.

The concept of the "average" or "typical" man or woman is, in a sense, illusive and nebulous. From the anthropometric standpoint, few can qualify as average in each and every respect (McCormick, 1964, p. 358). Since the average is the arithmetic mean of a quantitative measure only 50 percent of workers would be accommodated by designs dependent on average anthropometric data.

Percentiles permit a more realistic concept of the range of dimensions to be accommodated than does the mean value found in a normal distribution. Since extreme values represent rare occurrences, the upper and lower one percent of the specific population can be excluded for practical purposes. The use of percentiles gives a basis for estimating the proportion of the population who would be inconvenienced by any specific design, as well as aiding in the selection of equipment users and test subjects.

In the selection of workers, the known percentile limitations of the machine can eliminate misfits. The cost of medical care necessitated by stress from uncomfortable working positions can be controlled. Safety precautions are more likely to be heeded when the operator is not inconvenienced by machine design, which also would contribute to keeping medical costs low.

The objectives of this study were:

1. To determine a procedure for measuring space used by food service workers while operating quantity food production equipment.
2. To obtain anthropometric measurements of selected female food service workers.
3. To determine space used by these same food service workers while operating a 60 quart mechanical mixer.

REVIEW OF LITERATURE

Space Utilization

While standards exist for various aspects of food service activity; namely, preparation, storage and dining, there appears to be little information relating to space needed by workers carrying out specific activities. Thomas (1947) studied the application of industrial methods to institutional kitchen production. From data on the flow of materials through processing and of equipment usage, a method of determining equipment requirements for each meal's production was found.

Dana (1949) and Laschober (1960) published suggested space allocation for overall areas based on seating capacity of the dining room. Space allotments recommended by Kotschevar and Terrell (1961, p. 104) for dining room, production and related areas were based on seating capacity for cafeteria, college residence, counter service and table service. Recommendations for hospitals were based on bed capacity. Kotschevar and Terrell (1961, p. 82) recommended that linear space depths and height for work areas should be in terms of average human measurements. Specifications for various types of seating arrangements have been recommended for different food service operations. Avery (1965) suggested heights for work surfaces and widths for aisles in food production areas.

Burandt and Grandjean (1961) recommended table and adjustable chair dimensions based on investigations of the seating habits of office workers. A variety of consumer products and military hardware have been designed on the basis of data collected by Dreyfuss (1959).

Considerable research has been conducted and standards developed for space needs for certain household activities. In a study of space requirements for the home laundry, McCullough (1952) developed a measuring procedure which was used later in a cooperative project covering 36 different household activities (McCullough et al., 1962). Space used by the homemaker for laundry activities was defined. Movable wall panels were placed close to the worker and adjusted as a result of the subject's body movements until the maximum dimension was located. Attempt was made to correlate the subject's anthropometric measurements with space used. Within the limits of the study there appeared to be no correlation between body size and space needs. Work habits and body use, rather than body size, were determinants of space required.

Reliability and validity of the McCullough technique were tested by Klopfer _et al_. (1958). Design of the movable wall was modified because of the possibility that measurements obtained by McCullough's technique might reflect experimentor as well as subject error. The modified movable wall moved only in a direction parallel to the original position of the wall. Validity of the modified McCullough technique was measured against the space used when there were no restrictions. Motion-picture photography was used for direct measurement of such space utilization. Results of this study indicated that the magnitude of movement of the movable wall was a reliable measure of the space utilized and also was a valid measure of movement by the subject when the wall was present. Results were multiplied by a correction factor for each activity to provide a valid and reliable estimate of space utilization. For the determination of space standards for household activities (McCullough _et al_., 1962), both the McCullough technique and the modified movable wall (Klopfer _et al_., 1958) were used (Woolrich, 1965).

The McCullough wall panels were constructed of plywood supported by a light wooden frame attached to a horizontal base. Diagonal braces from the top of the panel to the outer side of the base maintained the panel in a true vertical position. Movement of the panel was facilitated by four castors mounted on the underside of the base (McCullough _et_.

al., 1956). The modified wall panel (Klopfer et al., 1958) was constructed of rigid transparent plastic supported by a metal frame. Wheels were welded to their axles to permit the panel to move straight backward when pushed, into a position parallel with its original one.

McCullough et al. (1962) could not establish a correlation between any specific anthropometric measurement and the space used. As in the laundry study (McCullough, 1952) and in a further laundry space requirements study by Nichols et al. (1961), body use and work habits rather than body size determined space utilization by homemakers.

The physiological cost of workplace dimensions to the homemaker (Knowles, 1946; Bratton, 1959), and to the industrial worker (Hudson, 1962) have been studied. Knowles (1946) studied the effects of ironing board height on metabolic rate, heart rate, respiratory rate, pulmonary ventilation, blood pressure, force exerted and postural shifting of homemakers. Results showed greater physiological cost when working on an ironing board that was always 31 inches high than when using a board that was three to four inches higher, with the specific height chosen by the subjects.

Standing to work and sitting to work under different conditions were compared by Bratton (1959). Oxygen consumption data were converted to energy cost in calories per minute. Results of the study showed that energy cost could not be cited as the basis of choice between sitting and standing to work, nor as justification for specifically designed equipment or work spaces for seated work.

Hudson (1962) compared standard work surface (40 inches from floor) for a standing operator versus an adjusted work surface (two inches below elbow point with arm hanging at side) in an industrial situation. Force exerted, measured by a force platform, was taken as the criterion. Results indicated less physiological exertion when working at the adjusted work surface than at the standard work surface.

Anthropometric Data

Anthropometric data for civilian populations are limited. McCullough *et al*. (1962) compared anthropometric data for homemakers participating in the space requirements study with measurements taken by O'Brien and Shelton (1941) for application to the women's garment and pattern construction industries. Barkla (1961) made estimations, from published data, of body measurements for the British population for seat design.

Considerable data have been collected by military organizations to establish standards for their particular needs; namely clothing and weapons. Because of the specific population involved, the data are not directly applicable to the general population (Damon *et al*., 1963).

PROCEDURE

The procedure for this study was adapted from that of McCullough et al. (1962) and data were obtained from two sources:

1. Anthropometric measurements
2. Measurements of actual space used by female food service workers while operating a free standing, floor model mechanical mixer.

Four subjects were chosen from a list of full-time female food service workers employed in bakery units of the Kansas State University Residence Halls. Participation by workers was voluntary, with no consideration given to extent of experience or efficiency (Appendix C, Table 8).

Anthropometric measurements were taken, using instruments located in the Family Economics Department Research Laboratory. Activity measurements were made while subjects operated a free standing, floor model 60 quart mechanical mixer installed in the Quantity Foods Preparation Laboratory of the Institutional Management Department. Thus the activity measurement was removed from an actual production setting.

Anthropometric Measuring

Measurements. Anthropometric data were obtained from the subjects at the following body sites and positions (Figures 1 and 2):

I. Height from floor (flatheeled shoes)

Code	Standing	Code	Sitting
H1.	Top of head	SH1.	Top of head
H2.	Eye	SH2.	Eye
H3.	Shoulder	SH3.	Shoulder
H4.	Elbow	SH4.	Elbow
H5.	Wrist	SH5.	Top of thigh
H6.	Thumb tip	SH6.	Top of knee
		SH7.	Top of crossed knee

II. Width

Code	Standing	Code	Sitting
W1.	Maximum body	SW1.	Lower body
W2.	Shoulders		
W3.	Upper body		
W4.	Lower body		

III. Length

Code	Standing	Code	Sitting
L1.	Shoulder to elbow	SL1.	Buttock to knee
L2.	Shoulder to wrist		

IV. Thickness

T1. Maximum body

T2. Lower body

V. Girth

G1. Bust

G2. Hips

VI. Weight

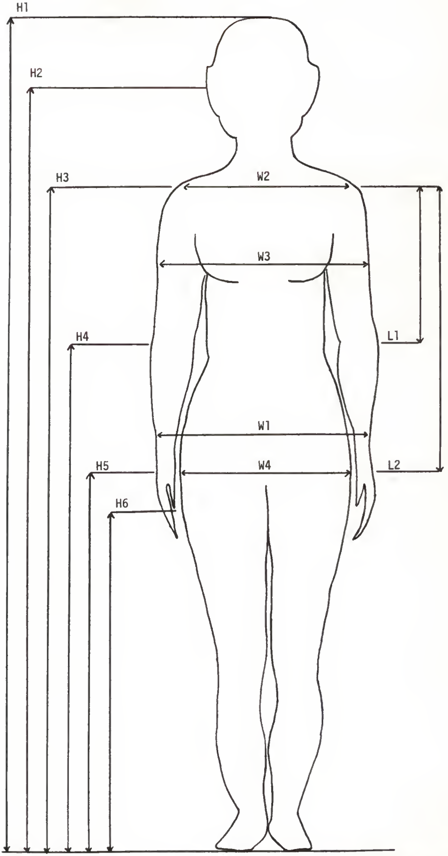

Figure 1. Sites for anthropometric measurements, standing subject (flat heeled shoes).

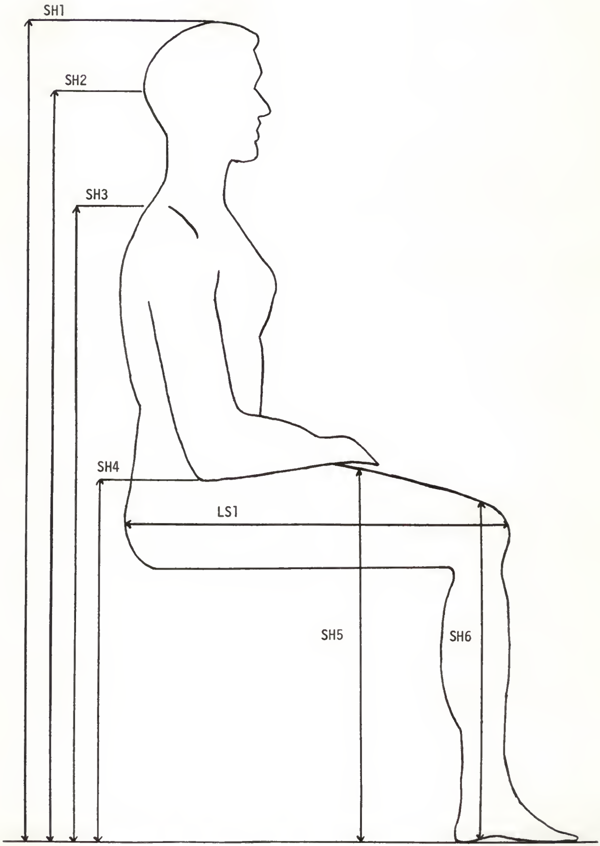

Figure 2. Sites for anthropometric measurements, seated subject.

Measurements were taken over garments, including shoes commonly worn when performing quantity food production activities. Clothing included a cotton uniform and flat heeled shoes.

Although anthropometric data obtained from seated subjects had no bearing on the current study it was considered advantageous to obtain such data while subjects were being measured. This was viewed as a contribution to the common pool of knowledge necessary for equipment and facilities design.

Equipment. The equipment used for anthropometric measuring included:

1. Anthropometer mounted on a four foot by two foot plywood base which had been cut out in front in a semicircle so that the subject could stand on the floor. This instrument was used to measure heights (Appendix A, Figure 6).
2. Sliding calipers for measuring widths and thicknesses (Appendix A, Figure 7).
3. A double beam scale, capacity 300 pounds, to measure weights.
4. A flexible non-stretchable tape to measure length and girth.
5. A wooden chair adjustable to subject's height for seated measurements.
6. Masking tape to indicate body landmarks on subject.

7. Two McCullough type wooden movable wall panels, one 60 inches by 48 inches, one 48 inches by 36 inches, each mounted on two and one half inch castors (Appendix A, Figures 8 and 9).
8. Steel measuring tape for measuring distances between wall panels.

Definitions of Body Landmarks. Body landmark definitions for this study were adapted from McCullough *et al.* (1956). Definitions were refined according to work of Stoudt *et al.* (1965), Appendix B.

Definitions of Measurements Taken. Each measurement was defined according to body site and physical position (Appendix B). Definitions were based on work of McCullough *et al.* (1956), and of Stoudt *et al.* (1965) with modifications for the anthropometric equipment available for this study.

Activity Measurement

Elemental Activities Affecting the Use of Space. Since most quantity food production activities necessitate changes in body position, certain common movements may affect the use of space. These movements have been termed "Elemental Activities" and defined (Appendix B) according to Woodson and Conover (1964) and to McCullough *et al.* (1956).

Equipment. The equipment used for measuring defined activities included:

1. Two movable wall panels, one 60 inches by 48 inches, one 48 inches by 36 inches.

2. Steel measuring tape.

3. Sliding calipers

Elemental Activities defined (Appendix B).

EA1. Width, elbows extended.

EA2. Bent at hips, arms down.

EA3. Bent at hips, reach from bent position.

EA4. One knee kneel (Figure 3).

Test Activity. Test activity was defined as consisting of all the motions required to prepare a specific food product using the mechanical mixer.

Equipment used for test activity included:

1. Mechanical mixer, Hobart model H - 600 T (Appendix A, Figure 10).
   60 quart bowl, 'B' flat beater.
   30 quart bowl, 'D' wire whip.

2. Two movable wall panels, one 60 inches by 48 inches, one 48 inches by 36 inches.

3. Cart, three tier, 30 inches by 18 inches.

4. Steel measuring tape.

Product prepared. Plain Cake (Fowler, West and Shugart, 1961, p. 90), recipe for 200 servings (Appendix B).

Method. Prior to actual testing subjects were given the opportunity to work under simulated conditions to help overcome possible inhibitory effects of the wall panels on body movement.

The subject was instructed to take a position close to the machine to operate the controls. A movable wall panel

EA1. Elbows extended.

EA4. One knee kneel.

EA2. Bent from hips, arms down.

Figure 3. Definitions of elemental activities.

was placed behind her. A second panel was placed at right angles to the first and as close to the subject as possible. A cart holding pre-weighed ingredients and utensils was located adjacent to the mixer to form the third boundary of the working area.

Although the plain cake recipe chosen did not call for the use of two mixing bowls, both were used to ascertain maximum space usage while operating the mixer. To keep the initial working area to a minimum, the 60 quart bowl holding the flat beater was placed next to the cart, but outside the defined area. The 30 quart bowl holding the wire whip was positioned under the mixer. The reduction ring for 30 quart bowl was placed on the second shelf of the cart (Figure 4).

The subject was instructed to work as she would naturally. As she moved and touched the wall panels they were adjusted by the experimentor to maximum distance necessary to carry out the operation. During the activity care was taken to keep the wall panels parallel to their original positions.

Measurements of maximum distance between the machine and movable wall panels were taken with a steel tape and recorded in whole numbers. Notes on subject's work habits and posture were made (Appendix C, Table 8).

Three measurements were made within the work area after the subject had completed the mixing process, but before the 60 quart bowl was removed from the machine (Figure 5). Lateral measurement from the outermost edge of the cart (C) to the movable wall panel (W1) has been designated as (L),

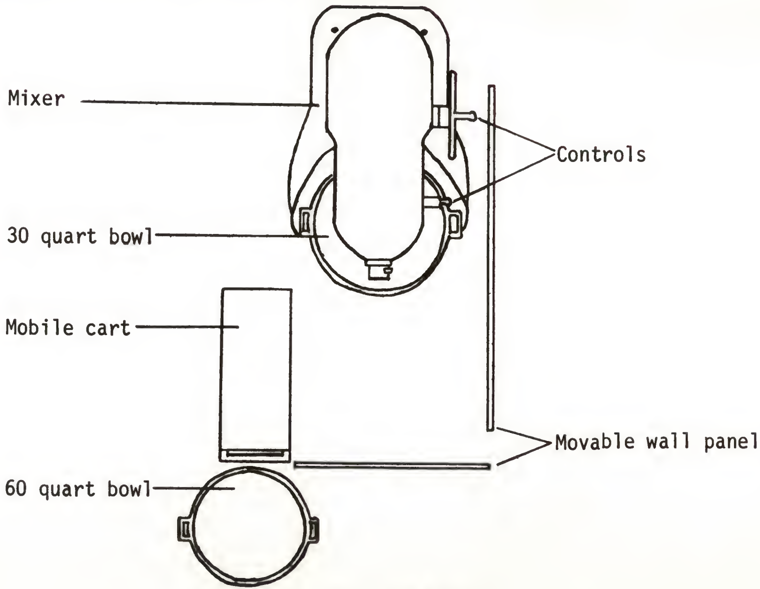

Figure 4. Work area layout.

EXPLANATION OF FIGURE 5

Work area layout after subjects had completed mixing cake.

Code: M - mixer

C - cart

W1. - movable wall panel

W2. - movable wall panel

30 - 30 quart bowl

60 - 60 quart bowl

L - lateral measurement from furthermost edge of cart to W1

D - depth measurement from back edge of bowl to W2

B - measurement from furthermost edge of bowl to W1

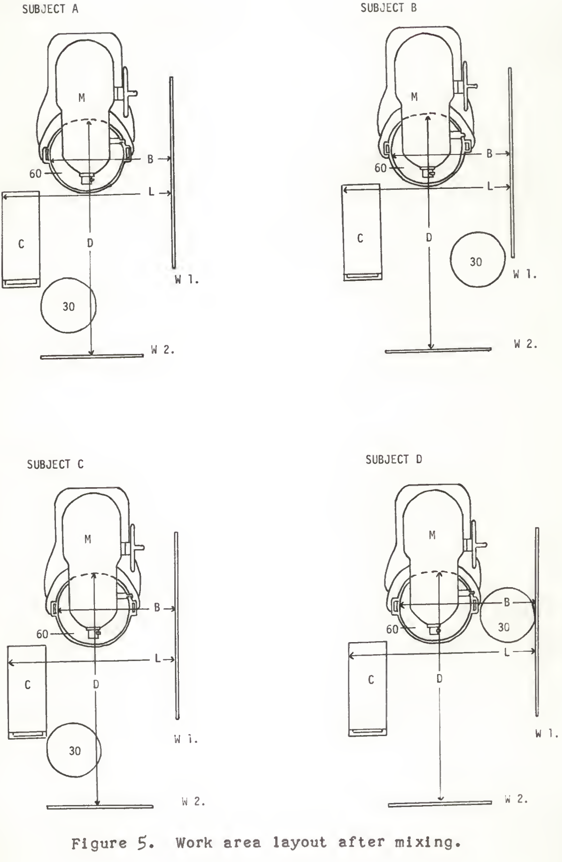

Figure 5. Work area layout after mixing.

that from the furthermost edge of 60 quart bowl to W1. as (B). Depth measurement from back of bowl to movable wall panel (W2) has been coded (D).

Area, in square feet, of work area after mixing was computed from (L) and (D). The measurement (L) was chosen for determination of area because the space used to transport ingredients from the cart to mixing bowl must be considered part of the activity. Similarly, in the choice of the back edge of the bowl as reference point for measurement (D), allowance was made for the scraping down process indicated in the Plain Cake recipe (Appendix B). Measurements could have been taken from the innermost edges of the cart and bowl but this would not have considered effects of subject's body movements, such as arm reach and bending.

Areas for each of three trials, made on different days, were obtained and the average for each subject was calculated. An additional trial was made when the measurements obtained showed that the subject used widely varying amounts of space. Data secured from the additional trials were included in the calculation of the individual subject's average.

RESULTS AND DISCUSSION

Anthropometric Measurements

Anthropometric data obtained from four subjects (Table 1) were compared with mean values obtained by McCullough _et al._ (1962). Mean height of the subject group approximated the

Table 1. Anthropometric measurements obtained from four subjects.

Anthropometric[a] measurements	Subject A	Subject B	Subject C	Subject D	Mean Subjects	Mean McCullough	Reference population[b]
Standing							
I. Height (inches)							
H1. (with shoes)	64.83	63.75	63.25	61.33	63.29	64.00	
H1. (without shoes)	64.00	63.12	62.25	60.20			
Percentile							
i) overall	65th	50th	40th	15th			U.S. Women, 1960-62 (Stoudt _et al._, 1965)
ii) by age	75th	60th	50th	10th			
H2. (without shoes)	59.67	58.87	57.83	57.76	57.76	59.5	
H3. (without shoes)	52.50	50.87	49.33	49.50	50.55	52.3	
Percentile	40th	30th	10th	15th			Air Force female basic trainees, 1953 (Damon _et al._, 1963)
H4. (without shoes)	37.50	38.37	36.25	37.37	28.03	39.6	
H5. (without shoes)	30.00	30.37	28.75	30.62			
H6. (without shoes)	24.17	23.37	24.25	25.62	24.35	26.6	

Table 1. (Contd.)

Anthropometric[a] measurements	Subject				Mean		Reference population[b]
	A	B	C	D	Subjects	McCullough	
II. Width (inches)							
W1.	18.50	21.00	16.83	20.50	19.21	18.4	
W2.	14.63	14.00	13.63	15.13	14.35	14.4	
W3.	18.00	19.75	16.50	20.50	18.69	17.8	
W4.	15.25	15.50	13.63	14.33	14.68	14.5	
Percentile	95th	100th	55th	80th			Air Force female basic trainees, 1953 (Damon *et al.*, 1963)
III. Length (inches)							
L1.	15.00	14.50	13.75	12.75	14.00		
Percentile	100th	95th	80th	30th			Army female personnel, 1949 (Damon *et al.*, 1963)
L2.	24.50	24.33	22.50	21.75	23.37		
IV. Thickness (inches)							
T1.	11.75	12.00	10.00	11.83	11.40	10.9	
T2.	11.50	12.75	10.13	12.83	11.80	10.7	
V. Girth (inches)							
G1.	41.00	46.50	36.00	45.50	42.25	36.6	
G2.	44.50	48.50	40.25	45.25	44.63	39.0	

Table 1. (Concl.)

Anthropometric[a] measurements	Subject				Mean		Reference population[b]
	A	B	C	D	Subjects	McCullough	
VI. Weight (pounds)							
	168.50	206.00	140.50	192.00			
Percentile							U.S. Women, 1960-62 (Stoudt et al., 1965)
i) overall	80th	95th	55th	95th			
ii) by age	75th	95th	40th	90th			
Shoe height (inches)							
	0.83	0.63	1.00	1.13			

[a] Sites for anthropometric measurements (Figure 1).

[b] Percentile values for reference populations (Appendix C, Table 6).

obtained by these workers, but body, width and thickness measurements showed greater variation. Where possible, classification of subjects' measurements by percentiles was made (Table 1) and values for reference populations given (Appendix C, Table 6).

Measurements taken while subject was seated on a chair adjusted to her height were recorded (Appendix C, Table 7) but since these measurements have no bearing on this study, mean values and percentile classifications were not determined.

Height and weight data have been compared with that obtained by Stoudt et al. (1965) from 58,343 American women during 1960-62. While test subjects were placed in 65th, 50th, 40th and 15th percentiles (Table 1) for height, individual subjects' weight percentiles were not the same as for height; for example subject D, 15th percentile for height and 95th for weight.

Lack of anthropometric data for civilian women necessitated comparison of other measurements with those obtained from military personnel (Damon et al., 1963). This revealed that lower body width of all subjects was greater than that of Air Force female basic trainees. Subjects A, B and D were classified into 95th, 100th and 80th percentiles respectively for this dimension. Similarly, comparison of shoulder to elbow length showed subjects A, B and C to be longer in that measurement than Army female personnel. Subjects A, B and C were found to be in the 100th, 95th and 80th percentiles respectively. These values represent the upper extreme in the distribution of measurements in the population and occur only rarely.

Activity Measurements

Elemental Activities. Data obtained for these activities (Table 2) were compared with mean values obtained from similar activities measured by McCullough et al. (1962).

Table 2. Elemental activity measurements.

Activity[a]	Subject A in.	Subject B in.	Subject C in.	Subject D in.	Mean Subjects in.	Mean McCullough in.
EA1.	32.63	33.13	31.33	32.00	32.27	33.6
EA2.	32.75	34.50	34.13	30.33	32.93	32.8
EA3.	44.50	33.33	39.75	38.25	38.96	45.0
EA4.	31.75	-	22.75	28.50	27.33	33.5

[a] Elemental activities (Figure 3).

For two activities, EA1 (Elbows extended) and EA2 (Bent at hips, arms down), the space used by test subjects was similar to the mean value of McCullough et al. (1962). A difference of 7.04 inches between the subjects' mean measurement and the mean for homemakers (McCullough et al., 1962) for EA3 (Bent at hips with reach) occurred. For EA4 (One knee kneel) the difference between the subjects' and homemakers' mean values was 6.17 inches. The evident obesity in the subject group may account for such variations, as obese persons experience greater difficulty in bending than do those of normal weight.

Test Activity. Greater individual differences occurred in lateral measurement (L) than in depth (D) (Table 3). The depth appeared to be controlled by movement of the 60 quart bowl into the working area. Three of the subjects used less space during Trial three than in Trial one (Table 3). Two factors probably influenced the use of less space: inhibitory effect of movable wall panel and subject's increased familiarity with method of mixing. Data obtained indicate the degree of individual fluctuation in space usage that is possible.

Comparison of elemental and test activity measurements (Table 4) does not show a marked relationship between EA2 (Bent at hips, arms down) and test activity area. Subject D, with shortest EA2 measurement, 30.33 inches, required more space for the test activity, 31.87 square feet, than other subjects. For EA3 (Bent at hips with reach) subject A with longest reach, 44.50 inches, required less space, 28.41 square feet, than two of other three subjects for test activity.

Anthropometric measurements of individual subjects apparently did not determine the amount of space each used for test activity. Subject A, who was tallest in height and who had longest shoulder to wrist measurement, used less space, 28.41 square feet, than subjects B and D (Table 5). Subject C, second shortest in height and in shoulder to wrist length, and of smallest girth used the least space,

Table 3. Test activity measurements.

Subject	Trial	Lateral Distance L[a] in.	B[b] in.	Depth D[c] in.	Area L x D sq. ft.
A	1	63.00	35.00	67.00	29.31
	2	65.00	35.00	64.00	28.89
	3	59.00	30.00	67.00	27.45
	4	60.00	30.00	67.00	27.92
	Average	61.75	32.50	66.25	28.41
B	1	63.00	36.00	68.00	29.75
	2	59.00	31.00	70.00	28.68
	3	59.00	31.00	70.00	28.68
	Average	60.33	32.67	69.33	29.03
C	1	64.00	33.00	70.00	31.11
	2	61.00	28.00	63.00	26.69
	3	59.00	30.00	69.00	28.27
	4	55.00	28.00	66.00	25.21
	Average	59.75	29.75	67.00	27.82
D	1	64.00	43.00	69.00	30.67
	2	71.00	43.00	65.00	32.05
	3	70.00	42.00	69.00	33.54
	4	70.00	42.00	64.00	31.11
	Average	68.75	42.50	66.75	31.87

[a] L, lateral distance from furthermost edge of cart (C) to movable wall (W1.).

[b] B, distance from furthermost edge of bowl to cart (C) to movable wall (W1.).

[c] D, depth from back edge of bowl to movable wall (W2.) (Figure 5).

Table 4. Comparison of elemental and test activity measurements.

Subject	Elemental activity		Test activity	
	EA2[a]	EA3	Lateral[b] distance L	Area
	in.	in.	in.	sq. ft.
A	32.75	44.50	61.75	28.41
B	34.50	33.33	60.33	29.03
C	34.13	39.75	59.75	27.82
D	30.33	38.25	68.75	31.87

[a] Elemental activities (Figure 3).

[b] L, distance from furthermost edge of cart (C) to movable wall (W1.) (Figure 5).

Table 5. Comparison of anthropometric and test activity measurements.

Subject	Anthropometric measurements			Test activity	
	Height[a]	Length[b]	Girth[c]	Lateral[d] distance	Area
	H1. in.	L2. in.	G2. in.	L in.	sq. ft.
A	64.83	24.50	44.50	61.75	28.41
B	63.75	24.33	48.50	60.33	29.03
C	63.25	22.50	40.25	59.75	27.82
D	61.33	21.75	45.25	68.75	31.87

[a] H1. Top of head, with shoes)
[b] L2. Shoulder to wrist) (Figure 1)
[c] G2. Hips)

[d] L, distance from furthermost edge of cart (C) to movable wall (W1.) (Figure 5).

27.82 square feet. Subject D, shortest in height, with shortest shoulder to wrist length and second greatest girth, used more space, 31.87 square feet, than remaining subjects. In part this was because she moved the 30 quart bowl from the mixer to the right of the machine (Figure 5).

Indirectly the subject's anthropometric measurements may have influenced the space used. The short, obese subject D had to take more steps to carry out some parts of the test activity; for example, operating the bowl lifting mechanism, whereas subject A could accomplish the same by reaching. Body movements, rather than body dimensions, appeared to influence the amount of space used to carry out the test activity.

SUMMARY

The relationship of food service workers to preparation and cooking equipment is a vital factor in the determination of space needs in food service operations. Their efficiency, safety and comfort in a mechanical environment are factors frequently overlooked. Although standards exist for space needs for household activities, the literature reviewed indicated a lack of information for quantity food production activities.

The objectives of this study were:

1. To determine a procedure for measuring space used by food service workers while operating quantity food production equipment.

2. To obtain anthropometric measurements of selected female food service workers.
3. To determine space used by these same food service workers while operating a 60 quart mechanical mixer.

Anthropometric data obtained included heights, widths, lengths, thicknesses, girth and weight.

The test activity consisted of mixing a plain cake by a method which involved the use of both 30 quart and 60 quart mixing bowls. Movable wall panels were placed close to the worker and adjusted as the result of the subject's body movement until maximum dimensions were located. The distance between the machine and wall panels was measured.

Body movement rather than body dimensions appeared to influence the amount of space used for the test activity. Subject A, tallest in height, 64.83 inches, with longest shoulder to wrist length, 24.50 inches, used less space, 28.41 square feet, than subjects B and D. Subject C, second shortest in height, 63.25 inches, and in shoulder to wrist length, 22.50 inches, and of smallest girth, used the least space, 27.82 square feet. Subject D, shortest in height, 61.33 inches, with shortest shoulder to wrist length, 21.75 inches, used more space, 31.87 square feet, than remaining subjects. Measurements obtained for elemental activities showed similar trends.

To establish space standards for the use of the 60 quart mechanical mixer, further work with a larger group of subjects is recommended. Data from this study suggests that the upper 95th percentile of food service workers should be accommodated by space standards developed.

RECOMMENDATIONS

Data obtained in this study suggest that in the development of space standards for quantity food production activities the upper 95th percentile of food service workers; namely those within fifth to 100th percentiles, should be accommodated.

Further study is necessary to determine the relationship of common body movements, those termed "Elemental Activities," to space used under food production conditions. To establish standards for the mechanical mixer, based on production activities, additional work with a larger number of subjects is recommended. These activities should include the use of the mixing bowls and attachments. Operations involving the use of other pieces of equipment; for example a vegetable slicer operated from the mechanical mixer, should be included in further studies. Before further work on space needs is undertaken, study should be made of work area arrangement incorporating principles of time and motion economy.

The technique employed in this study was simple to use, measure and record. Training of the research worker to obtain anthropometric data should be undertaken to ensure accurate location of body landmarks and sites for measurements required. Practice in the use of the anthropometric instruments is essential. Care is necessary when controlling the movement of movable wall panels to maintain the relative position parallel to the original location.

It is possible that a more accurate estimation of space needs for food service workers may be obtained if the distance between the mixing bowl lifting mechanism and the movable wall parallel to the machine were measured. Since some body movement is required to turn the lifting mechanism, the space used is likely to vary more than the distance from the furthermost side of the bowl. The space used to operate the lifting mechanism would affect the positioning of other equipment adjacent to the mixer. If the lifting mechanism is chosen as the reference point for the lateral measurement (L), it should also be the point from which depth (D) is measured.

The positioning of equipment on the side away from the controls should be determined by the space needed to clean and maintain the machine. This aspect of the machine's use could be studied.

Woolrich (1965) suggested that wall panels constructed of rigid transparent plastic supported by a light aluminum frame and mounted on castors may help overcome inhibitory effects on subjects' body movements of wooden wall panels.

Based on the variety of household activities measured by McCullough _et al_. (1962) the procedure adopted in this study could be used in determining food service workers' space needs for a wide range of quantity food production equipment and activities.

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APPENDIX A

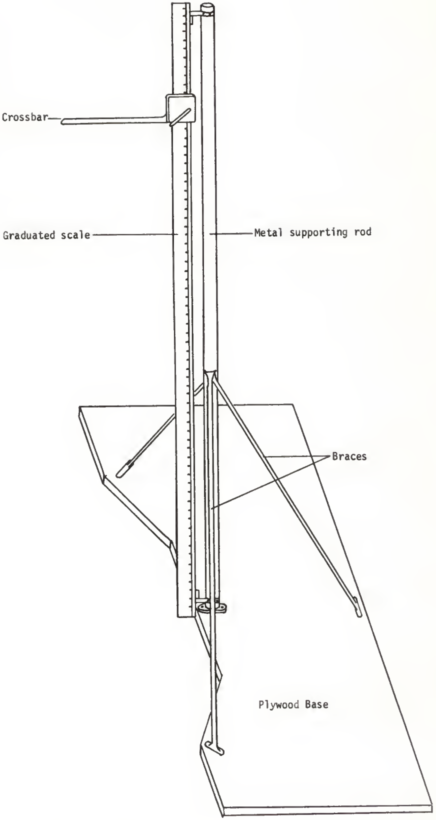


Figure 6. Anthropometer.

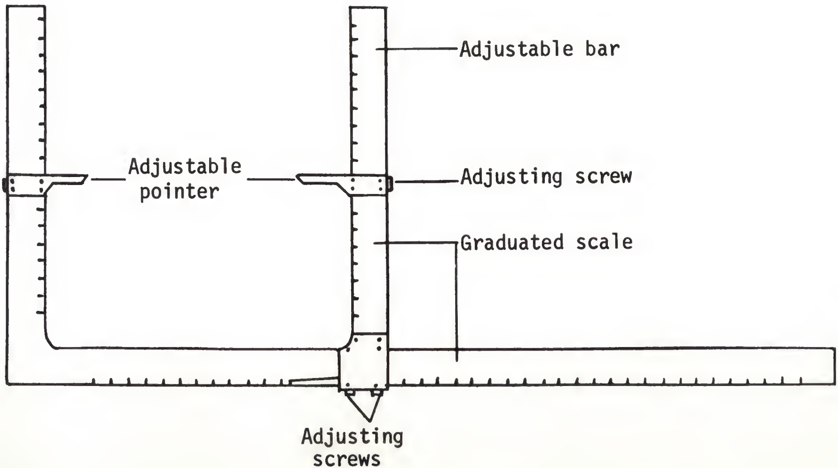


Figure 7. Sliding caliper.

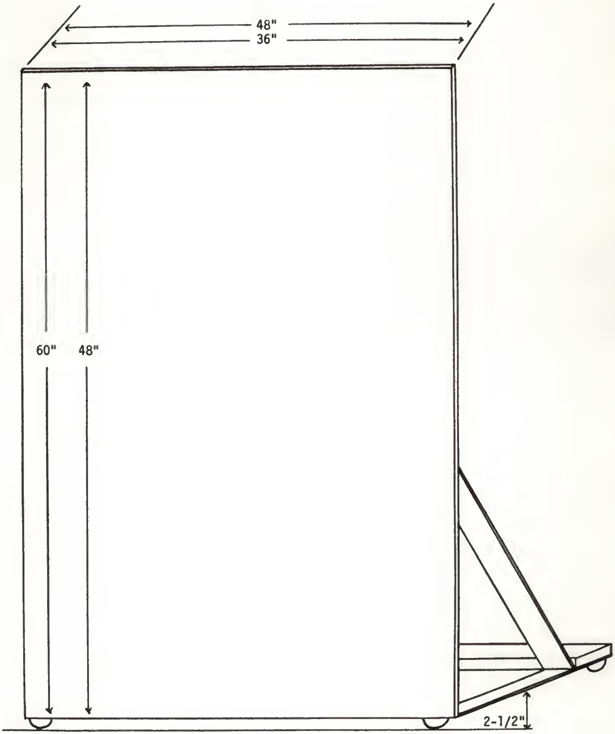


Figure 8. McCullough type movable wall panel, front view.

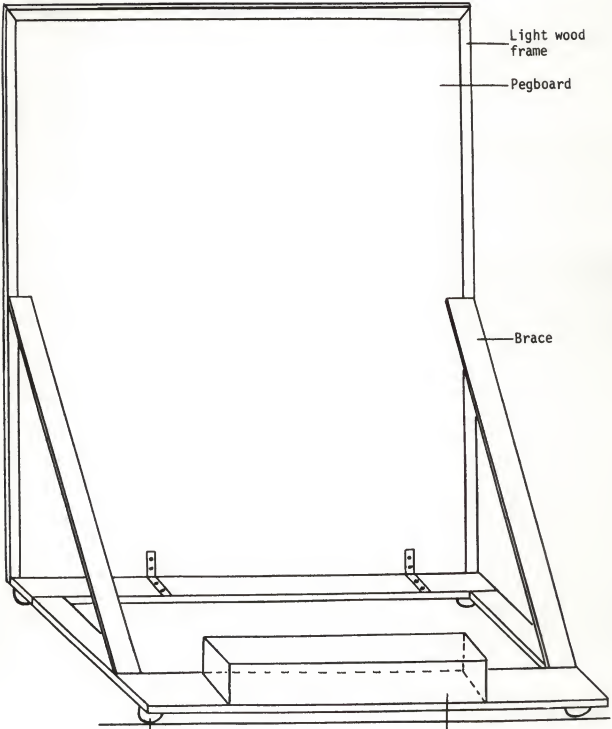
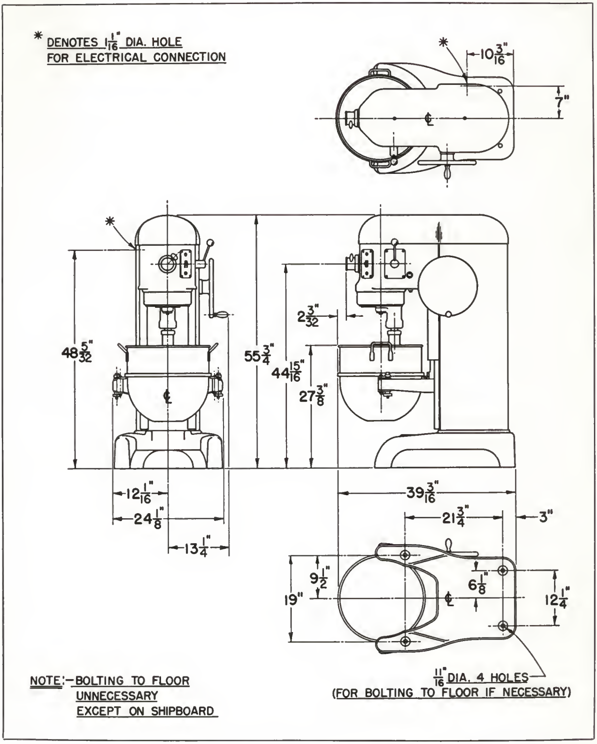


Figure 9. McCullough type movable wall panel, rear view.

DETAILS and DIMENSIONS MODEL H-600



PRINTED IN U.S.A.

Net Weight — 753 lbs.
Approx. Shipping Weight — 928 lbs.

Figure 10. Dimensions of mixer. Specifications from Hobart Manufacturing Company.

APPENDIX B

DEFINITIONS

Body Landmarks

(McCullough *et al*., 1956; Stoudt *et al*., 1965)

Acromion. The acromion is defined as the most laterally projecting point of the acromial process of the scapula. Both right and left acromions will be marked. While the point is being located the subject will stand with her back to the measurer. The measurer will identify the lateral edge of the prominence at the shoulder level by pressing her fingers against the bone. The most lateral point will be judged by palpation. This point will be marked with a small patch of masking tape.

Olecranon. The olecranon is the prominence of the ulna projecting behind the elbow joint. The point of greatest projection posteriorly will be marked when the subject's forearm is fully flexed and the posterior surface seen in profile. The subject will stand with her back to the measurer.

Most Anterior Point of Patella. The subject will place the right foot on a chair, with the lower leg in a line perpendicular to the floor and the knee bent at right angles. The measurer will sit on a low stool at subject's side, with her eyes on a level with the bent knee. The point of greatest anterior projection as seen in profile will be marked.

Outer Corner of the Eye. The subject will stand with head in the Frankfort horizontal plane, namely, that horizontal plane that includes the lower margin of the bony orbit - the bony socket containing the eye - and the supratragal notch above the anterior cartilaginous projection of the external ear. A mark will be made where an imaginary line crosses the socket bone.

Wrist Joint. The wrist joint will be defined as the distal point of articulation of the radius with the ulna which is indicated by the bony prominence of the outer wrist.

Hip Level. The measurer will stand in front of subject, and with her index and middle finger palpate the region of the trochanter with the direction of palpation from below upward. To help locate the exact level the subject will be asked to bend slightly forward. A rounded depression known as the bench will be located and marked. Hip level will be determined for both right and left sides.

Points of anatomical reference (Figure 11).

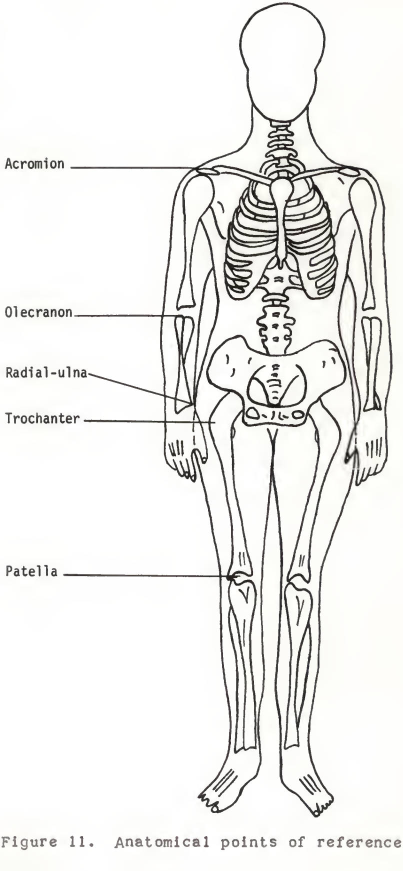


Figure 11. Anatomical points of reference.

DEFINITIONS

Anthropometric Measurements

(McCullough *et al.*, 1956; Stoudt *et al.*, 1965)

Height

Standing

H1. Top of Head. The subject will stand erect in front of the anthropometer with her back to it, looking straight ahead with head in Frankfort horizontal plane, arms by side, palms on thighs, weight evenly distributed with both feet as close together as is comfortable. The subject will move back until some part of her body touches the anthropometer. The measurer will lower the crossbar of the anthropometer until it rests on top of subject's head, compressing the hair if necessary. The crossbar will be set and reading made.

H2. Eye. The subject and measurer will assume the same positions as for H1. The crossbar will be lowered to the eye landmark of the right eye, set and reading taken.

H3. Shoulder. The subject will stand as for H1. but with right shoulder to the anthropometer. The measurer will stand to the right and slightly behind the subject. The crossbar will be lowered to the acromion point of right shoulder, set and measurement taken.

H4. Elbow. The subject and measurer will assume the same positions as for H3. The subject will hold her arm so that a right angle will be formed by the upper arm hanging straight and the forearm parallel to the floor. The crossbar will be lowered to the olecranon of the right arm, set and reading taken.

H5. Wrist. The subject will stand as for H3. with her arms hanging loosely at the side with fingers straight but not rigid. The crossbar will be lowered to the wrist joint of the right arm, set and reading taken.

H6. Thumb Tip. The subject will stand as for H5. The crossbar will be lowered to the thumb tip of the right hand, level sighted and reading taken.

Sitting

Measurements of the seated subject will be made with subject seated on a chair, adjusted for height, with feet comfortably placed on the floor, lower leg perpendicular to the floor at right angles to upper leg and body erect but not rigid. The height of the chair at center front and center back of the seat will be measured, using the anthropometer.

SH1. Top of Head
SH2. Eye
SH3. Shoulder
SH4. Elbow

The measurements will be taken using the same body landmarks and physical location of both subject and measurer as for standing heights.

SH5. Top of Thigh. The subject and measurer will assume the same positions as for SH3. The crossbar will be lowered to the junction of the abdomen and subject's right thigh, set and reading taken.

SH6. Top of Knee. The subject and measurer will assume the same positions as for SH3. The crossbar will be lowered to the highest point of the subject's right knee, set and reading taken.

SH7. Top of Knee, Legs Crossed. The seated subject will cross her right leg over her left at the knee, with the left foot on the floor as for SH3. The crossbar will be lowered to the highest point of subject's right knee, set and reading taken.

Width

Standing

W1. Maximum Body. The subject will stand erect, weight evenly distributed with feet as close together as comfortable, arms by sides and palms on thighs. The measurer will stand directly behind subject. The caliper will be held parallel to floor and moved up and down until point of greatest width is located. The movable bar will be set and readings taken.

W2. Shoulders. The subject and measurer will stand as for W1. The fixed bar of the caliper will be placed against subject's left acromion landmark. The movable bar will be set against the right acromion landmark, set and reading taken.

W3. Upper Body. The subject and measurer will stand as for W1. The measurement of greatest upper body width will be taken at a point determined by moving the caliper up and down to find the greatest width of body, including arms, at the waistline, or above the waist and below acromion.

W4. Lower Body. The subject will stand erect, weight evenly distributed with feet as close together as comfortable and hands clasped together at the waist. The measurer will stand directly behind subject and hold caliper parallel with floor. The fixed and movable bars will be fitted together on either side of the waist. The caliper will be expanded as needed and lowered until greatest width below the waist is located.

Sitting

SW1. Lower Body. The subject will sit as for SH3. The measurer will sit on a low stool behind subject. The caliper will be held parallel to floor with fixed bar against subject's left side at the farthest extension sidewise. The movable bar will be adjusted until it touches the widest part of thigh or hip on right side, bar set and reading taken.

Length

Standing

L1. Shoulder to Elbow. The subject will stand as for H4. The measurer will stand to right of subject. The length from the right acromion to right olecranon will be measured with a flexible non-stretchable tape.

L2. Shoulder to Wrist. The subject and measurer will assume the same positions as for L1. The length from the right acromion to right wrist joint will be measured with a flexible non-stretchable tape, care being taken to pass the tape over the right olecranon while taking the measurement.

Sitting

SL1. Buttock to Knee. The subject will sit as for SH3. The measurer will sit on low stool at subject's right side. The caliper will be held parallel to floor, with fixed bar against subject's right buttock. The movable bar will be extended until the midpoint of the patella is located, bar set and reading taken.

Thickness

T1. Maximum Body. The subject will stand as for W1. The measurement will be obtained by placing a movable wall panel touching the point of greatest extension forward of subject while standing. Another movable wall panel will be placed touching the point of greatest extension backward of subject. The distance between the two walls will be measured with a steel measuring tape.

T2. Lower Body. The subject will stand as for W4. The measurer will stand at subject's right side and facing her. The caliper will be held parallel with floor, with movable bar to front. The caliper will be moved up and down until the point of greatest thickness below the waist is found, bar set and reading taken.

Girth

G1. Bust. The subject will stand erect, feet as close together as comfortable, arms hanging naturally at sides. The measurer will stand in front of subject. A flexible non-stretchable tape will be passed around the point of greatest extension to the front, and across the back below the scapulas, keeping the tape parallel with the floor. The girth measurement will be taken without constriction.

G2. Hips. The subject and measurer will assume the same positions as for G1. The measurer will pass a flexible non-stretchable tape around the subject over the points indicating the trochanters, keeping the tape parallel with floor.

DEFINITIONS

Elemental Activities

EA1. Width, Elbows Extended. (Woodson and Conover, 1964). The subject will stand with arms flexed in horizontal plane, wrists straight, palms down, fingers straight and together, and thumbs touching chest. The measurer will stand directly behind subject and hold caliper parallel with floor. The fixed bar of caliper will be placed against left olecranon and movable bar adjusted to touch the right olecranon, set and reading taken.

(McCullough *et al*., 1956)

EA2. Bent at Hips, Arms Down. The subject will bend forward so that the body forms a right angle. A wall panel will be placed behind subject touching point of maximum extension to the rear, and a second wall panel will be placed in front of subject touching the forward extension of the head. The distance between the wall panels will be measured with a steel tape.

EA3. Bent at Hips, Reach from Bent Position. (Buttocks to thumb tips with arms extended.) The subject will bend forward as in EA2. but with arms extended forward and with thumb and index finger in grasping position. Wall panels will be placed in front and behind subject at the points of maximum extension. The distance between the wall panels will be measured with a steel tape.

EA4. One Knee Kneel. The subject will kneel on one knee. A wall panel will be placed behind subject touching the foot extended to the rear. A wall panel will be placed in front of subject touching the point of greatest extension in front. The distance between the wall panels will be measured with a steel tape.

Data Form Anthropometric Data

Name________________ Age____years Date__________

Address________________ VI. Weight_______lbs.

I. Height

Standing			Sitting		
H1.	Top of head	______in.	SH1.	Top of head	______in.
H2.	Eye	______	SH2.	Eye	______
H3.	Shoulder	______	SH3.	Shoulder	______
H4.	Elbow	______	SH4.	Elbow	______
H5.	Wrist	______	SH5.	Top of thigh	______
H6.	Thumb tip	______	SH6.	Top of knee	______
			SH7.	Top of knee crossed	______

II. Width

Standing			Sitting		
W1.	Maximum body	_____in.	SW1.	Lower body	_______in.
W2.	Shoulders	_____			
W3.	Upper body	_____			
W4.	Lower body	_____			

III. Length

Standing			Sitting		
L1.	Shoulder to elbow	______in.	SL1.	Buttock to knee	______in.
L2.	Shoulder to wrist	______			

IV. Thickness			V. Girth		
T1.	Maximum body	_____in.	G1.	Bust	______in.
T2.	Lower body	_____	G2.	Hips	______

Shoe heel height__in. Chair height, front__in. Back__in.

Data Form   Elemental Activity Measurements

Name_______________________________ Age____years

Address____________________________ Date________

EA1. Width, arms extended ______________in.

EA2. Bent at hips, arms down, length_____

EA3. Bent at hips, reach from bent position, buttocks to thumb tip_____

EA4. One knee kneel _____

Data Form   Test Activity Measurements

Name________________________ Age_____years Date______

Address____

Test Activity, TA______________________________________

Date	Trial	Length in.	Depth in.	Notes

RECIPE FOR PLAIN CAKE

(Fowler, West and Shugart, 1961)

		50	200
Flour		1 lb. 9 oz.	6 lb. 4 oz.
Fat		10 oz.	2 lb. 8 oz.
Baking powder		$2\frac{1}{2}$ T.	5 oz.
Sugar	a	1 lb. 14 oz.	7 lb. 8 oz.
Salt	a	$1\frac{1}{2}$ t.	2 T.
Milk	a	$1\frac{1}{4}$ c.	1 qt.
Eggs, whole	b	5	20
Milk	b	1 2/3 c.	1 qt.
Vanilla	b	1 T.	2 oz.

Method

1. Mix eggs, milk and vanilla (b).
2. Mix flour, fat and baking powder 2 min. in mixer bowl (low speed). Scrape down bowl and mix 3 min. more.
3. Add sugar, salt and milk (a). Mix 2 min. (low speed) and scrape down bowl; mix 3 min. more.
4. Add $\frac{1}{2}$ egg-milk mixture, mix 30 sec. Scrape down bowl; mix 1 min. Add remainder of mixture. Mix 1 min. Scrape down. Mix $2\frac{1}{2}$ min.
5. Pour into oiled pans, 12" x 20".
6. Bake 30-35 min. at 350° F.
7. Serving 2" x $2\frac{1}{2}$".

APPENDIX C

Table 6. Percentile values for reference populations.

Anthropometric measurement	Percentiles						Reference population	Source
	1st	5th	50th	95th	99th	S.D.		
Standing								
I. Height (inches)								
Top of head without shoes	57.1	59.0	62.9	67.1	68.8		U.S. women, 58,343 18-79 yr. 1960-62	Stoudt et al. (1965)
Shoulders without shoes	46.9	48.2	51.9	55.4	57.3	2.18	Air Force female basic trainees, 1953	Damon et al. (1963)
II. Width (inches)								
Lower body	12.2	12.5	13.5	15.4	16.9	0.95	Air Force female basic trainees, 1953	Damon et al. (1963)
III. Length (inches)								
Shoulder-elbow	11.3	11.9	13.1	14.3	14.9	0.74	Army female personnel, 1949	Damon et al. (1963)
VI. Weight (pounds)	93	104	137	199	236		U.S. women, 58,343 18-79 yr. 1960-62	Stoudt et al. (1965)

Table 7. Anthropometric measurements from four subjects.

Anthropometric[a] measurement	Subject			
	A	B	C	D
Sitting				
I. Height (inches)				
SH1.	50.75	49.50	51.25	49.33
SH2.	46.00	45.33	46.00	45.25
SH3.	27.63	38.63	37.83	38.83
SH4.	25.00	25.75	24.00	27.83
SH5.	23.50	21.63	22.63	22.25
SH6.	22.00	20.50	20.75	19.75
SH7.	26.33	26.63	25.63	27.75
II. Width (inches)				
SW1.	14.63	15.75	13.83	15.75
III. Length (inches)				
SL1.	22.75	22.00	21.25	21.33
Chair height	17.73	17.00	17.33	17.00

[a] Sites for anthropometric measurements (Figure 2).

Table 8. Subjects' work positions.

Subject	Age yrs.	Experience in present position yrs.	Work position during test activity
A	60	6	To front and control side of machine.
B	62	2	To front and left side of machine. Considerable body movement during Trial 1, very little in Trial 3.
C	57	4	To front of machine. Accustomed to operating similar machine in confined space.
D	40	2	To front of machine. Always placed dry ingredients in 60 quart bowl while mixing eggs and milk in 30 quart bowl. Considerable body movement.

SPACE REQUIREMENTS FOR QUANTITY FOOD PRODUCTION ACTIVITIES
USE OF MECHANICAL MIXER

by

BERNICE ELISABETH KELLY

Diploma in Home Science
University of Otago, New Zealand, 1954

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Institutional Management

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1966

ABSTRACT

The relationship of food service workers to preparation and cooking equipment is a vital factor in the determination of space needs in food service operations. Their efficiency, safety and comfort in a mechanical environment are factors frequently overlooked. Although standards exist for space needs for household activities, the literature reviewed indicated a lack of information for quantity food production activities.

The objectives of this study were:

1. To determine a procedure for measuring space used by food service workers while operating quantity food production equipment.
2. To obtain anthropometric measurements of selected female food service workers.
3. To determine space used by these same food service workers while operating a 60 quart mechanical mixer.

Anthropometric data obtained included heights, widths, lengths, thicknesses, girth and weight.

The test activity consisted of mixing a plain cake by a method which involved the use of both 30 quart and 60 quart mixing bowls. Movable wall panels were placed close to the worker and adjusted as a result of the subject's body movement until maximum dimensions were located. The distance between the machine and wall panels was measured.

Body movement rather than body dimensions appeared to influence the amount of space used for the test activity. Subject A, tallest in height, 64.83 inches, with longest shoulder to wrist length, 24.50 inches, used less space, 28.41 square feet, than subjects B and D. Subject C, second shortest in height, 63.25 inches, and in shoulder to wrist length, 22.50 inches, and of smallest girth, used the least space, 27.82 square feet. Subject D, shortest in height, 61.33 inches, with shortest shoulder to wrist length, 21.75 inches, used more space, 31.87 square feet, than remaining subjects. Measurements obtained for elemental activities showed similar trends.

To establish space standards for the use of the 60 quart mechanical mixer, further work with a larger group of subjects is recommended. Data from this study suggests that the upper 95th percentile of food service workers should be accommodated by space standards developed.