THE HUMAN BODY IN RELATION TO SPACE NEEDS OF FOOD SERVICE EQUIPMENT

by

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INTRODUCTION

Modern food service kitchens operate today with mechanized equipment and convenient layout. In planning space needs for kitchen equipment, the architect, food service consultant, dietitian, or restaurateur needs to be concerned with the human body, its structure and mechanical function, for it is an important part of the man-machine system.

The equipment manufacturer's specification provides data for initial space allocation. However, the space needs of the food service employee to efficiently operate, clean and maintain the equipment is more difficult to determine and often is neglected in the systems design. Failure to provide a few inches can be critical, for it may jeopardize the operation and performance of the man. Oven doors opening into a work aisle that is too narrow to accommodate both the open door and worker; a machine placed so close to a wall that the operator is unable to effectively use the control buttons are examples of this negligence. With forethought the critical inches can be provided without compromising the layout design, thus providing food service workers with the safety and comfort needed to work in the mechanical environment.

Woodson and Conover (1964) reported that the ancient artists as far back as the Greeks or earlier studied bodymember relationships and developed a "rule of thumb" for ideal proportions of the adult figure. They further stated, "the human torso has some very important characteristics that should be considered whenever men must fit into a work space and must serve not only as the connecting link between the limbs but also as the elastic link for

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extending some of these limbs."

The most powerful tool available today for the optimal sizing of many mass-produced items from oxygen masks to airplane cockpits and truck cabs are reliable anthropometric data and procedures (Damon, et al., 1966, p. 3).

A cleverly engineered piece of equipment may be abused or destroyed by an uncomfortable or inefficient operator unless the human body has been kept in mind from planning stages of design. Ideally, equipment should be adjustable so all men are able to operate the machines and for this purpose the anthropometric percentiles are more important than the mean. Mean or average refers to the middle or 50th percentile, but since very few can qualify as "average" or "typical" from the anthropometric standpoint, percentiles give a more realistic concept of the range of dimensions that can accommodate a group. The extreme values often represent chance occurrences which may be disregarded in designing equipment. (Damon, et al., 1966, p. 16). The designer should try to accommodate at least 90 per cent of the predetermined users.

If the percentage of operators qualifying for the operation of the equipment is known, then the selection of employees can be more realistic to the needs of the system. Undue physical exertion may be eliminated, maximum efficiency maintained, and safety precautions are more likely to be observed if the operator is not inconvenienced. Maintenance is more apt to occur and thus a reduction of cost upkeep if space is allowed for easy removal for repairs and cleaning.

The objectives of this study were:

1. To obtain the anthropometric measurements of a limited number of female food service workers.

2. To study the space needs of the same food service workers using a vertical cutter/mixer.

REVIEW OF LITERATURE

Space Requirements

Design of work space in food systems is dependent both on static and dynamic variables (McCormick, 1965). Information on the static variables is more readily available than the dynamic variables, which are dependent mainly on motion of human body members as well as equipment and materials movement. It is possible to treat motion of a body member in space as essentially two-dimensional, one dimension along the line of motion and the other along the height axis. But most motions of the human body are three-dimensional and so far there has been no accurate way of predicting these motions (Katlan and Nadler, 1969).

Psychologically there seems to be an effect of confinement that causes the human body to fatigue rapidly within confined spaces (Moore, 1962). Therefore allowances should be made when specifying operator's space to satisfy the physical need to stretch and relax muscles.

Templates often are used to evaluate plant layouts (Muther and Wheeler, 1962; and Moore, 1962). Plant layout templates are scaled to represent the machine, materials handling equipment, a workman, or even materials, but they do not take into account the specific dimensions of a worker and his actions.

Dana (1949) recommended at least four linear feet of work table space for each preparation employee and ample aisle clearance between cooking equipment. For oven equipment the minimum aisle space recommended is three feet six inches, and where portable wagons are used, an aisle of four feet.

Space requirements are best determined by grouping equipment requirements into work centers and then determining dimension in terms of space needs for people, equipment, raw food items, supplies, partially processed food, and working and traffic aisles (Montag and Tamashunas, 1969). This means that space needs to be allowed for worker access to equipment, swinging doors, tilting pieces of equipment, and handling large pieces of equipment, but there is no "rule of thumb" to guide designers.

To design an efficient kitchen layout, Kotschevar (1968) suggested going through the actual motions of the work to be done considering the body of the worker who is to function in the center. Templates, chalk lines, or an actual scale plan may be helpful in making such a study.

Avery (1965) developed recommendations for table heights and aisle space. He further noted that kitchen equipment should be grouped into most used combinations and arranged in the proximity and order of most frequent interuse, proceeding from receiving to storage to preparation to cooking, and finally to holding and service.

Space requirements for production areas in cafeteria, college residence, counter service and table service usually are based on the number served, according to Kotschevar and Terrell (1961, pp. 109, 111). Figures given for square feet of kitchen space per meal for food facilities of different types and sizes are tentative suggestions and should be measured carefully in terms of specific needs. Linear space, depths, and heights for work centers should be controlled in terms of average human measurements.

In recent years industrial engineers have begun to apply the techniques of probability theory and mathematical statistics in facilities design and space utilization (Smalley and Freeman, 1966). Students enrolled in industrial engineering courses at Kansas State University learn how to locate one new item in an existing facility using a mathematical formula (Konz, 1970), but cost and customer are the criteria in determining the location rather than space needs.

Four basic computerized programs for layout planning are currently available in the United States (Muther and McPherson, 1970). They are CRAFT (Computerized Relative Allocation of Facilities Technique), CORELAP (Computerized Relationship Layout Planning), ALDEP (Automated Layout Design Program), RMA Comp I (Richard Muther and Associates Contribution to the field). Three of the four require the amount of space for each activity to be known as part of the input data.

According to McCullough, et al., (1962), body use and work habits rather than body size determine space utilization by homemakers. In a test activity by Kelly (1965) using a large mixer, anthropometric measurements of individual subjects apparently did not directly determine the amount of space used for a test activity.

A machine operator is functional, not a static template or a manikin. He may have to perform complex movements or assume unusual positions. He requires an adequate visual field inside and outside his workspace. In addition, he must be kept comfortable, safe, and efficient (Damon, et al., 1966).

Research has been conducted on the space needs for certain household activities. McCullough, et al., (1962) studied space requirements for a home laundry, developing a measuring procedure that was used later to cover 36 different household activities. Movable wall panels were placed near the subject and adjusted according to his body movements until the maximum dimension was located. There seemed to be no correlation between the subject's anthropometric measurements and the space used. Work habits and body use rather than body size seemed to determine space needs.

Klopfer, et al., (1958), tested the validity and reliability of the McCullough technique of measuring. Design of the movable wall was modified because there was the possibility of experimenter's error as well as subject's error. The modified movable wall moved only in the direction parallel to the original position of the wall. Space measurement using motion picture photography was used to check the validity of the modified McCullough technique.

Wall panels constructed of plywood supported by a light wooden frame attached to a horizontal bar were the type used by McCullough. The panel remained in a true vertical position by diagonal braces from the top of the panel to the outer side of the base. Four casters mounted on the underside of the base facilitated movement of the panel (McCullough, et al., 1962).

Klopfer, et al., (1958), used a rigid transparent plastic supported by a metal frame for the modified wall panel. To permit the panel to move straight backward into a position parallel with its original use, wheels were welded to their axles.

In discussing body motions Frazer (1953) stated that in general, body motions do not do productive work but merely get the body in a position to do productive work and as such should be eliminated whenever possible. Combined motions are those that occur when two or more motions are performed by the same body member at the same time. Simultaneous motions are those that are performed at the same time by two or more body members. Motions requiring neither conscious thought nor direction can be performed simultaneously, while those requiring both conscious thought and direction cannot.

See (1972) reminds us that human engineering design data, requirements, measurements, and measurement techniques are available to provide for maximal efficiency, comfort and safety for all our "operator-equipment systems" and work environments. She concedes that most measurements on "man-machine systems" have been done by and for the military but that data on other employees should be sought.

Anthropometric Data

Anthropometric data may be used for two purposes (Murrell, 1965, p. 36):

1. To determine the size and shape of the equipment which a man is to use.
2. To determine the space in which a man is to work.

These two purposes will not always require the same dimensions. The use of anthropometric data has been largely in the design of military equipment. Civilian measurements have been used mainly for designing clothing or footwear, and as a result many dimensions that would be useful to machine designers have not been taken. The designer wants dimensions that relate to an active person and usually they have been those of the static individual. For example, knowing the reach of the hand to the tips of the fingers is of little value when what really is required is the best distance from the body for grasping and operating a control efficiently. Functional anthropometry may be the term used for work done on the anthropometry of the active man.

Anthropometric charts were developed after many years of research by Henry Dreyfuss (1960). A number of body measurements are quite closely related (Murrell, 1965, p. 40). When the relationship is known, key measurements such as stature, weight, and girth that are much more easily obtained from large populations may assist in obtaining a number of detailed dimensions. In this way functional measurements, which have been obtained on a comparatively small section of individuals, can be extended to cover much larger sections of the community.

Damon, et al., (1966), stated that the time of day can affect measurements, principally heights. "A person will lose height after being up and about owing to compression of the intervertebral discs. Body heights are greatest upon arising and least before retiring." Weight, on the other hand, is generally least in the morning and may vary up to two per cent of total body weight.

O'Brien and Shelton's (1941) study of women provided detailed anthropometric measurements that are excellent for garment and pattern construction but consist mostly of body heights, circumferences, and skin surface measurements, only a few of which relate to equipment design. Measurements of the civilian population is represented chiefly by studies of the aged (Roberts, 1960; Damon and Stoudt, 1963) and by groups like truck and bus drivers and college students.

Anthropometric measurements of six food service workers and the space needed to operate a food chopper attachment to a mixer were tabulated by McManis (1970). It was noted that the two smaller women used more body movements and took more space performing the task than women of greater height and width. Another factor in the amount of space needed to do the task may have been work habits since the two smaller subjects had worked for food service a shorter period of time.

PROCEDURE

The procedure for this study was adapted from McCullough, et al., (1962), Kelly (1965) and Damon, et al., (1966). Data were obtained from two sources:

1. Anthropometric measurements.
2. Actual space measurements used by female food service workers while operating a vertical cutter/mixer machine.

Thirteen female subjects, employees of residence hall food service, were chosen for the anthropometric measurements and seven participated in the activity measurement. Participation was voluntary with consideration given to ability to operate the machine but not to length of experience.

Anthropometric measurements were taken using instruments located in the Department of Foods and Nutrition Laboratory and McCullough type movable wall panels from the Department of Family Economics. Activity measurements were made while subjects operated a 60E model vertical cutter/mixer installed in Derby Food Center. The activity was measured in an actual production setting.

Anthropometric Measuring

Equipment. The equipment used for anthropometric measuring included:

1. Anthropometer mounted on plywood base to measure heights.
2. Sliding steel caliper for measuring widths and thickness.
3. Double beam scale, capacity 300 pounds, to measure weights.
4. Marking pencil to determine point of measure.
5. Wooden ruler to use as right angle level for marking.
6. 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 casters.

7. Steel tape for measuring distances between wall panels, and distances from floor to point of measure.

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

I. Height from floor--standing

1. Top of head
2. Eye
3. Shoulder
4. Elbow
5. Knuckle
6. Arm reach

II. Breadth-Depth--standing

7. Chest breadth
8. Hip breadth
9. Chest depth
10. Buttock depth
11. Maximum body depth
12. Maximum body breadth

III. Weight--pounds

IV. Age--years

Measurements were taken over garments commonly worn when performing quantity food production activities. The clothing included a cotton uniform and flat-heeled shoes.

Measurements defined. Definitions were based on work of Damon, et al., (1966) and Kelly (1965), with modifications for the anthropometric equipment available.

1. Top of head. The subject stands erect in front of the anthropometer with her back to it and heels placed easily together. The subject moves back until some part of the body touches the anthropometer. The subject looks straight ahead but never strains head back. The measurer lowers the crossbar of the anthropometer until resistance of the skull is felt. The crossbar is set and reading made.

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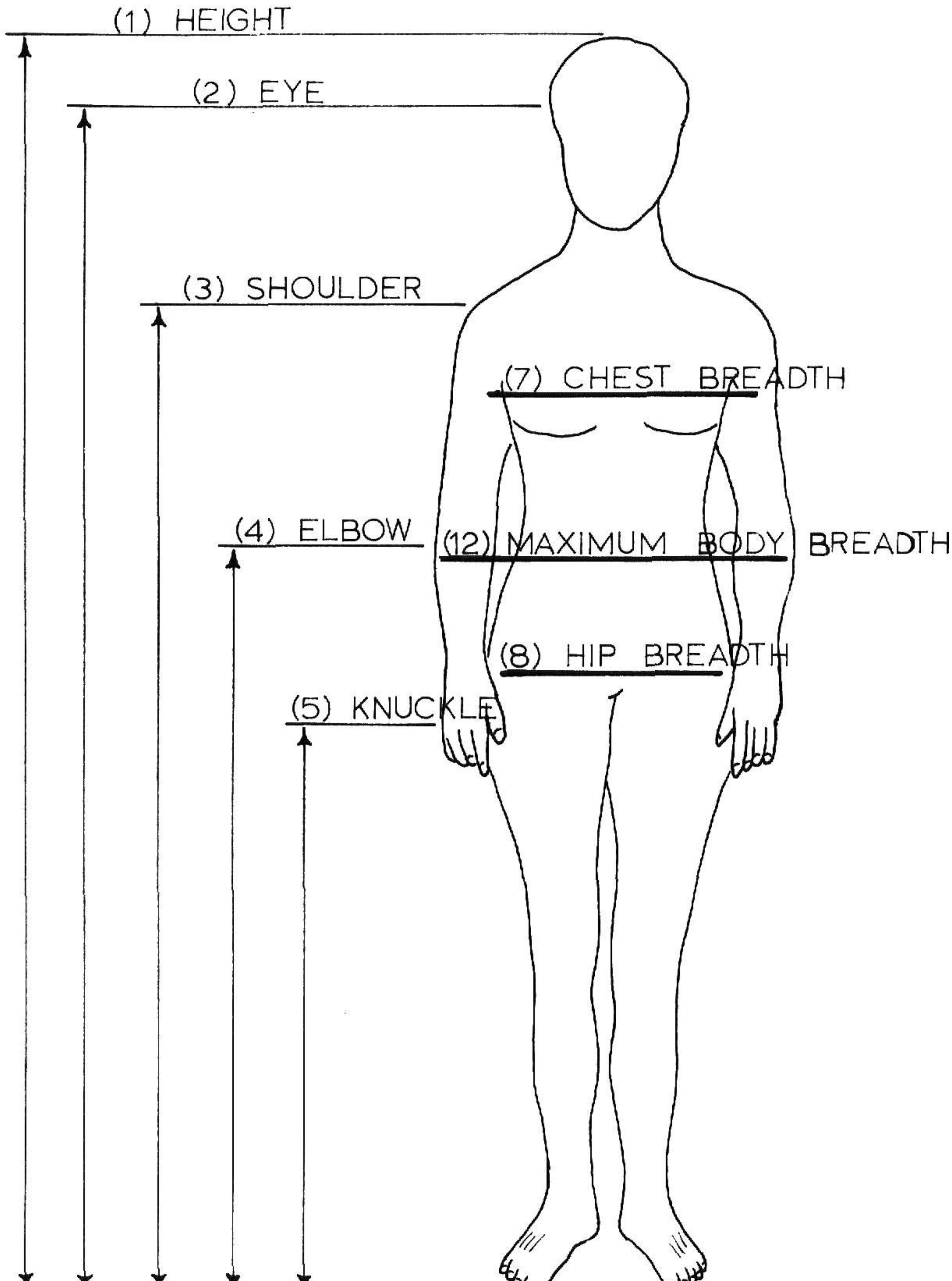

Figure 1. Sites for anthropometric measurements.

2. Eye. The subject and measurer assume the same position as for 1, feet as close together as comfortable, eyes directed forward, arms at side, palms placed on thighs. The measurer stands to the subject's right, lowers the leveler to the inner corner of the right eye, set and reading taken.
3. Shoulder height. The subject assumes the same position as for 1, but with right shoulder to the anthropometer. The measurer stands to the right and slightly behind the subject. The crossbar is lowered to the acromion point of right shoulder, set and measurement taken.
4. Elbow. The subject and measurer assume the same positions as for 3. The subject holds her arm so that a right angle is formed by the upper arm hanging straight and the forearm parallel to the finger. The crossbar is lowered to the olecranon of the right arm, set and reading taken.
5. Knuckle. The subject and measurer assume the same positions as for 3. The crossbar is lowered to the largest knuckle of the middle finger, set and reading taken.
6. Arm reach. The subject stands erect against a wall, feet as close together as comfortable, eyes directed forward, buttocks and shoulders pressed against the wall. The right arm and hand are extended forward horizontally and maximally. A wall panel is moved forward until it touches the longest finger and the distance measured with a steel tape.

7. Chest breadth. The subject stands erect, with arms at her sides and palms on thighs. The measurer stands directly in front of the subject. The caliper is held parallel to floor and the horizontal distance across the chest at nipple level is read.

8. Hip breadth. The subject stands erect, weight evenly distributed with feet as close together as comfortable, with arms at her sides and palms on thighs. The measurer stands directly behind the subject. The caliper is held parallel to the floor and the maximum horizontal distance across the hips measured. The movable bar is set and readings taken.

9. Chest depth. The subject stands erect, arms hanging naturally at sides, breathing normally. The measurer stands at the right side of the subject. The caliper is held parallel to the floor and the horizontal distance from front to back of the chest level where the fourth rib meets the sternum or breastbone is measured. On the female subjects this is the horizontal distance from front to back of chest at nipple level.

10. Buttock depth. The subject stands erect, arms hanging naturally at sides, breathing normally. The measurer stands at the right side of the subject. The caliper is held parallel to the floor and the horizontal distance between buttocks and abdomen at the level of the maximum protrusion of the buttocks is measured. The

movable bar is set and reading taken.

11. Maximum body depth. The subject stands erect, with arms hanging naturally at her sides. The movable walls are moved in, one to the front and one to the back until touching the subject. The distance is measured with a steel tape, giving the horizontal distance from the most anterior post to the posterior point.

12. Maximum body breadth. The subject stands erect, with arms at her sides. The movable mounted walls are moved in, one to the right side and one to the left side until touching the subject on both sides. The maximum breadth across the body including the arms is measured using a steel tape to measure the distance between the two walls.

Activity Measurement

The activity consisted of placing twelve heads of lettuce in the 78-quart vertical cutter/mixer machine, an activity that occurs daily when chopping lettuce for salads. The equipment consisted of:

78-quart vertical cutter/mixer, Hobart Model 60E (Appendix A, Fig. 7)

2 movable wall panels with casters,
 one 60 inches by 48 inches
 one 48 inches by 36 inches

1 barrel--20 inches in diameter, 24 inches high

1 metal dolly with casters, 28 inches in diameter

Steel measuring tape.

Procedure.

1. The subject assumed a position close to the vertical cutter/mixer in a manner most convenient for her to operate the machine. Each subject, who was an experienced operator of the machine, was asked to bend over to the bottom of the barrel to reach a head of lettuce, thus giving maximum depth needed to accomplish the task.
2. Barrels on mobile stands were used to hold the produce and were stationed to the right of the operator.
3. "Walls in." The wall panels were placed touching the subjects in the initial position and were moved, as the subject worked, to the maximum distance needed to carry out the activity. The wall panels were kept in position parallel to the machine.
4. "Walls out." The subject worked freely while the measurer estimated the point of maximum extension and moved the walls in to define the area.
5. The maximum distance between the machine and the wall panels was measured with a steel measuring tape.
6. Measurements were recorded in whole numbers to the nearest inch. Measurements and work habits were noted and recorded. Depth and lateral measurements were taken from the front center of the machine at the point where the motor is attached to the lid.
7. Each subject repeated the activity twice with the walls touching her in the initial position, i.e., with "walls

in," and twice when the walls were moved in to define the area of activity, i.e., with "walls out."

8. Trials were taken on two different days to secure normal variation in fatigue and emotional status.
9. The four trials were averaged to give the space needed by each subject.

The subjects were instructed to work as they would normally. Water needed for the operation was in the bowl. The activity consisted of taking twelve heads of lettuce out of a barrel, putting them in the vertical cutter/mixer bowl, closing the lid and securely fastening it. The operator moved to the front of the machine to turn the switch on and off rapidly to chop the lettuce. The operation of the machine requires alertness and swiftness so the product will not be over-cut.

Measurements of maximum distance between the center of the machine and movable wall panels were taken with a steel measuring tape and recorded. Lateral measurements from the center of the machine have been designated (L). Depth measurements from the center of the machine to the movable wall panel parallel to the machine have been designated (D). Area in square inches after chopping the lettuce was computed from (L) and (D) using the mean of the four trials.

Statistical Analysis

Data were analyzed by the Kansas State University Statistical Laboratory. The means, standard deviations, standard errors and critical values were determined by computer programming. With available data, a simple correlation of each anthropometric measurement in relation to total area used was noted and a multiple regression made of selected correlating measurements.

Statistical analyses were designed to note the range of anthropometric measurements of food service workers; determine correlation of each anthropometric measurement with total amount of space used to operate a vertical cutter/mixer; and correlate any group of measurements with total space used to operate a vertical cutter/mixer.

The means of all anthropometric measurements were analyzed and were compared to Kelly's (1965) study. Percentile for height and weight of food service workers were in relation to 7,162 females of the civilian population measured by the United States National Health Examination Survey in 1960-62. (Damon, et al., 1966)

RESULTS AND DISCUSSION

Anthropometric Measurements

Anthropometric measurements for 13 food service workers, ranging in age from 23 to 62, are shown in Table 1. Individuals' heights range from 57.8 to 70.5 inches with a mean of 63.8 inches. Weight varied from 103 to 286 pounds with a mean of 173 pounds.

Arm reach of subject K was the shortest, 28.25 inches, even though measurement from floor to the shoulder was longer than eight other subjects. Subject C with the greatest weight, 286 pounds, also showed the greatest maximum body width and breadth. Variation in measurement of the buttock depth showed the widest range from 8.8 inches of subject D to 18.4 inches of subject C. The maximum body depth corresponds to the buttock depth except for subjects B and D, who show a larger chest depth than buttock depth.

Mean values of each measurement were compared with those obtained by

TABLE 1.--Anthropometric dimensions (inches) obtained from thirteen subjects

Anthropometric measurements	Subject													Mean	
	A	B	C	D	E	F	G	H	I	J	K	L	M	McManis' subjects	Kelly's subjects
1. Height from floor standing															
1. Top of head (inches)															
With shoes	58.30	61.00	62.50	63.00	63.90	65.40	65.50	61.75	62.25	70.75	64.00	69.25	62.75		
Without shoes	57.80	60.25	61.75	62.25	63.15	64.50	64.50	61.50	62.00	70.50	63.50	69.00	62.50	63.88	63.90
Percentile															
i) overall	7th	22nd	37th	43rd	53rd	68th	68th	34th	40th	98th	57th	96th	46th		
ii) by age	8th	22nd	37th	33rd	54th	75th	69th	6th	46th	98th	55th	97th	52nd		
2. Eye (without shoes)	53.50	56.25	58.65	58.15	58.75	60.93	60.40	58.00	57.75	66.25	59.00	64.00	59.00	59.30	58.53
3. Shoulder (without shoes)	48.90	51.05	52.85	51.75	52.85	54.03	55.20	52.00	51.75	59.25	53.25	57.00	53.00	53.30	50.55
4. Elbow (without shoes)	36.50	38.25	44.25	39.75	39.25	40.03	42.00	40.00	38.50	45.00	41.50	43.00	45.00	41.00	37.37
5. Knuckle (without shoes)	25.30	26.25	29.13	28.05	28.15	27.03	30.20	26.50	25.50	27.75	28.50	28.00	27.50	27.50	
6. Arm reach (with shoes)	29.00	30.75	33.63	29.06	33.56	33.25	32.25	28.50	32.00	33.75	28.25	34.00	32.68	31.70	

TABLE 1.--cont.

Anthropometric measurements	Subjects													Mean	
	A	B	C	D	E	F	G	H	I	J	K	L	M	McManis' subjects	Kelly's subjects
II. Breadth--standing															
7. Chest breadth	11.90	13.20	16.70	10.30	12.20	11.80	12.40	14.00	12.30	12.90	11.20	13.50	15.90	12.95	
8. Hip breadth	13.60	14.20	18.20	12.80	15.20	13.50	16.70	15.80	13.50	15.70	14.60	17.40	17.70	15.30	14.68
9. Chest depth	10.20	12.80	14.60	9.20	10.60	10.60	12.00	10.90	10.30	9.90	9.40	11.30	17.70	11.49	
10. Buttock depth	10.20	12.10	18.40	8.80	11.00	10.70	12.60	11.90	11.40	11.50	10.40	11.70	18.00	12.20	11.80
11. Maximum body depth	11.12	14.12	18.60	9.80	13.00	12.25	13.19	12.00	12.00	14.00	12.00	12.50	18.25	13.29	11.40
12. Maximum body breadth	18.30	19.60	24.00	16.30	19.90	18.10	20.10	16.00	19.00	21.00	18.50	22.00	23.00	19.68	19.21
III. Weight--lbs.	130.5	179.0	286.0	116.5	158.00	141.4	194.6	103.0	153.0	206.0	139.5	190.5	260.0	173.0	176.7
Percentile															
i) overall	47th	79th	99.7th	37th	67th	55th	86th	28th	63rd	91st	53rd	85th	99th		
ii) by age	42nd	76th	99.5th	58th	63rd	44th	86th	33rd	57th	91st	61st	82nd	98th		
IV. Age--years	47	47	57	26	53	57	43	27	62	38	23	48	55	44	

Kelly (1965) for four food service workers. The mean height of 13 subjects was 0.1 inch shorter than the mean height of Kelly subjects, but the mean eye measurement was 0.8 inch longer than in Kelly's study. Distance from the floor to the elbow for 13 subjects showed a 3.6 inch higher measurement than Kelly's, this being the greatest mean variation. The next highest variation was in the maximum body depth with the 13 subjects having a greater mean depth of 1.89 inches.

Height and weight data have been compared with that obtained from the civilian population of American women during 1960-62 by U. S. National Health Examination Survey (Damon, et al., 1966). The test subjects varied in height from the 7th to 98th percentile overall. The percentile for height in their own age groups varied from the 8th to the 98th percentile. For civilian women the 99th percentile for height is 69.0 inches and the 95th percentile, 67.3 inches. The 98th percentile for height of food service workers tested was 70.5 inches, a difference of 1.5 inches taller than the civilian population women. Kelly subjects varied in height from the 15th to 65th percentile.

Weight of the test subjects varied overall from 108 to 286 pounds, or from the 28th to the 99th percentile. By age group the weight percentile varied from 33rd to 99th. All but the heaviest one per cent of civilian women weigh 234 pounds or less, and the 50th percentile weigh 135 pounds (Damon, et al., 1966). The four subjects Kelly (1965) used for her study were over the 50th percentile.

While test subjects varied in height from the 7th to the 98th percentile, their weights were not in the same range. For example, subject C was 37th percentile in height and 99th percentile for weight, and subject A was 7th percentile in height and 47th percentile for weight. The tallest subject

J ranked 98th percentile in height and 57th percentile in weight.

Activity Measurements

Data obtained from the activity measurements are recorded in Table 2. To find the total area used the distance from the center of the machine to the wall panel at right angles (L) was multiplied by the distance from the center of machine to the wall panel parallel with the machine (D). More space is required for the lateral movement than the depth movement. The lateral measurement included loading the machine, which consisted of taking lettuce from a barrel and placing in the machine, while the depth measurements involved movement of switch operations at the front of the vertical cutter/mixer (VCM). The differences in measurements taken on two separate days did not vary more than five inches. Taking measurements in the actual setting and being familiar with the operation of the VCM machine may have been influencing factors for space needed to operate it.

The space required by each subject to operate a vertical cutter/mixer is compared to selected anthropometric measurements in Table 3. The space varied from 776.73 square inches to 1,149.76 square inches, with a mean of 980.41 square inches. Subject C, with the greatest body breadth of 24 inches and greatest body depth of 18.6 inches, took more space for the test operation than the other six subjects. However, subject C made fewer body movements and more deliberate motions than the smaller subjects A and D. Subjects A and D, smaller in stature, operated faster and quicker but also made many more movements and steps than C. Subject D, with smallest maximum body depth of 9.8 inches and maximum body breadth of 16.3 inches, required 1,089.43 square inches to operate the machine, which is more space than the subjects

TABLE 2.--Test activity measurements, inches

Trials	Subjects													
	A		B		C		D		E		F		G	
	L[1]	D[2]	L	D	L	D	L	D	L	D	L	D	L	D
Trial 1, wall in	36.25	27.44	41.25	30.13	37.00	31.19	36.75	27.25	38.19	24.50	34.00	24.19	35.13	26.00
Trial 3, wall in	36.50	24.50	32.75	28.00	36.44	33.44	39.31	27.31	37.13	25.00	32.00	22.75	32.31	27.31
Mean	36.38	25.97	37.00	29.07	36.72	32.32	39.31	27.31	37.66	24.75	33.00	23.47	33.72	26.66
Trial 2, wall out	35.69	25.75	34.31	34.75	36.44	31.69	39.82	28.81	37.00	24.63	33.75	24.69	34.75	24.00
Trial 4, wall out	34.44	25.69	39.00	30.25	34.88	30.75	38.19	27.86	37.13	24.25	32.00	22.69	33.00	25.63
Mean	35.07	25.72	36.66	32.50	35.66	31.22	39.01	28.34	37.07	24.44	32.88	23.69	33.87	24.81
Overall mean	35.73	25.85	36.83	30.79	36.19	31.77	39.16	27.82	37.37	24.60	32.94	23.58	33.80	25.74
Total area = L x D = Sq. in.	923.62		1,134.00		1,149.76		1,089.43		919.30		776.73		870.01	

[1]Distance from the center of machine on motor attached to the lid to wall panel at right angles with the machine.
[2]Distance from the center of machine on motor attached to the lid to wall panel parallel with the machine.

TABLE 3.--A comparison of measurements to space required

Subject	Height inches	Arm reach inches	Body depth inches	Body breadth inches	Space required inches	Space required square inches
A	57.80	29.00	11.20	18.30	35.73 x 25.85	923.62
B	60.25	30.75	14.12	19.60	36.83 x 30.79	1,134.00
C	61.75	33.63	18.60	24.00	36.19 x 31.77	1,149.75
D	62.25	29.06	9.80	16.30	39.16 x 27.82	1,089.43
E	63.15	33.56	13.00	19.90	37.37 x 24.60	919.30
F	64.50	33.25	12.25	18.10	32.94 x 23.58	776.73
G	64.50	32.25	13.19	20.10	33.80 x 25.74	870.01

A, E, F, and G required, all with larger maximum body depth and body breadth measurements. Subject F, one of the tallest of the group (64.5 inches) and with one of the longest arm reaches of 33.25 inches, required fewer square inches of space (776.73 square inches) while operating the VCM than subject A, shortest in height (57.8 inches), with one of the shortest arm reaches of 29.0 inches. Subject F weighed 141 pounds and subject A weighed 130.5 pounds.

A simple correlation coefficient of each anthropometric measurement to total square inches needed to operate a vertical cutter/mixer is shown in Table 4. There was no significant correlation at the 0.01 or 0.05 level between measurements or any group of measurements of the food service workers in relation to the amount of space required for the test activity.

The height of individuals showed a significant correlation to the distance from the floor to eye, shoulder, elbow and arm measurements at the 0.01 level. Correlation between maximum depth and maximum breadth to weight, arm reach and buttock depth was significant at the 0.01 level. Weight showed a significant correlation at the 0.01 level to the chest depth, hip breadth, chest breadth, buttock depth, maximum depth, and maximum breadth measurements.

A multiple regression of the measurements of eye, elbow, knuckle, hip breadth, buttock and maximum depth to the "area in" and "area out" showed no significant correlation.

SUMMARY

A relationship exists between space provided for food service workers who use equipment and effective operation. The performance may be jeopardized

TABLE 4.--Simple correlation coefficients for anthropometric measurements to operate a vertical cutter/mixer

Variable	Area in	Area out	Weight	Arm reach	Head	Buttock depth
Head	-0.19	-0.28	0.23	0.63*	--	NS
Eye	-0.21	-0.30	0.29	0.67*	-0.98**	NS
Shoulder	-0.19	-0.30	0.34	0.67*	0.98**	0.63*
Elbow	-0.12	-0.25	0.74**	0.55*	0.65**	0.63*
Knuckle	0.32	0.14	0.43	0.29	NS	NS
Arm reach	-0.06	-0.13	0.65*	--	0.64*	NS
Chest brdth	0.06	0.01	0.79**	NS	NS	0.94*
Hip brdth	0.11	-0.02	0.78**	NS	NS	NS
Chest depth	0.002	0.009	0.79**	NS	NS	--
Buttock	0.02	-0.02	0.88**	NS	NS	--
Max depth	0.03	0.01	0.95**	0.57*	NS	0.91**
Max brdth	0.13	0.04	0.95**	0.72**	NS	0.79**
Weight	0.12	0.04	--	0.65*	NS	0.88**

* Significant at 0.05 level

** Significant at 0.01 level

NS Not significant

if a few inches critical to the operator is not provided. Since man cannot be changed, his dimensions, capabilities and limitations form the basis to improve system efficiency.

Standards have been established for space needs for military operations and household activities, but literature reviewed showed more information is needed for quantity food production.

The objectives of this study were:

1. To obtain anthropometric measurement of selected female food service workers.
2. To study the space needs of the same food service workers using a vertical cutter/mixer.

Anthropometric data included heights, weights, body breadth, body depths, arm reaches, shoulder heights and hip breadth.

The activity test consisted of placing twelve heads of lettuce in the vertical cutter/mixer, moving to the switch box, turning the machine on then off, and opening the machine lid. Movable wall panels were placed close to the worker and adjusted as the result of the subject's body movements until maximum dimensions were made. The distance between the center of the machine and wall panels was measured.

The influencing factor for the amount of space used appeared to be body movements rather than body dimensions. Subject F, tallest in height, 64.5 inches, with one of the longer arm reaches of 33.24 inches, and weighing 141 pounds (overall 55th percentile) used less space than subject A, shortest in height, 57.8 inches, with one of the shortest arm reaches of 29.0 inches and weighing 130.5 pounds (overall 47th percentile).

Subject D, with smallest maximum body depth of 9.8 inches and maximum body breadth of 16.3 inches, required (1,089.43 square inches) more space to operate the machine than subjects A, E. F, and G, all with larger maximum body depth and maximum breadth measurements.

Body measurements showing correlations were the eye, shoulder, and head; maximum body depth, buttock depth, and chest depth; and maximum breadth, elbow and arm reach. Weight showed a significant correlation at the 0.01 level to the chest depth, hip breadth, chest breadth, buttock depth, maximum depth, and maximum breadth measurements. However, no one measurement showed a significant correlation to the square inches needed for operation of a vertical cutter/mixer.

A multiple regression of the measurements of eye, elbow, knuckle, hip, buttock and maximum depth to the "area in" and "area out" showed no significant correlation.

CONCLUSIONS AND RECOMMENDATIONS

More total space was required to operate the VCM than operation of a 60 quart mixer (Kelly, 1965) or an 80 quart mixer with attachments (McManis, 1970). In the development of space standards for the vertical cutter/mixer, further studies are needed of body movements required to empty, clean, and maintain the machine. Body movement more than body dimensions seemed to influence the space needs to operate the VCM, which is in agreement with Kelly (1965) on space needs required for a mixer.

Data from this study suggests rather than precise formulas which might be universally applicable, a range of human dimensions be studied and the upper 95th percentile of food service workers be accommodated.

For quantity food production activities, one would critically appraise the relevance of existing data to his own situation. In planning space needs, a range of human dimensions and body movements to fit the group to be accommodated should be specified rather than dimensions of a single piece of equipment. The measured group needs to be representative of the equipment user and anthropometric measurements done according to established standards to ensure accurate location of body landmarks and sites for measurements. The use of movable walls to determine distance of body movements is a standard measurement easily adapted to food production activities. The techniques used in this study were simple to use, measure, and record, and could be used to determine food service workers' space needs for the wide range of quantity food production equipment.

Anthropometric measurements of a larger number of subjects need to be taken to yield a better representation of food service workers. Space allotments around equipment for body movement in the preparation of quantity foods should be studied further.

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A special tribute to the participating food service workers in the residence halls for the project would not have been possible without the voluntary participation, cooperation and interest of each.

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APPENDIX A

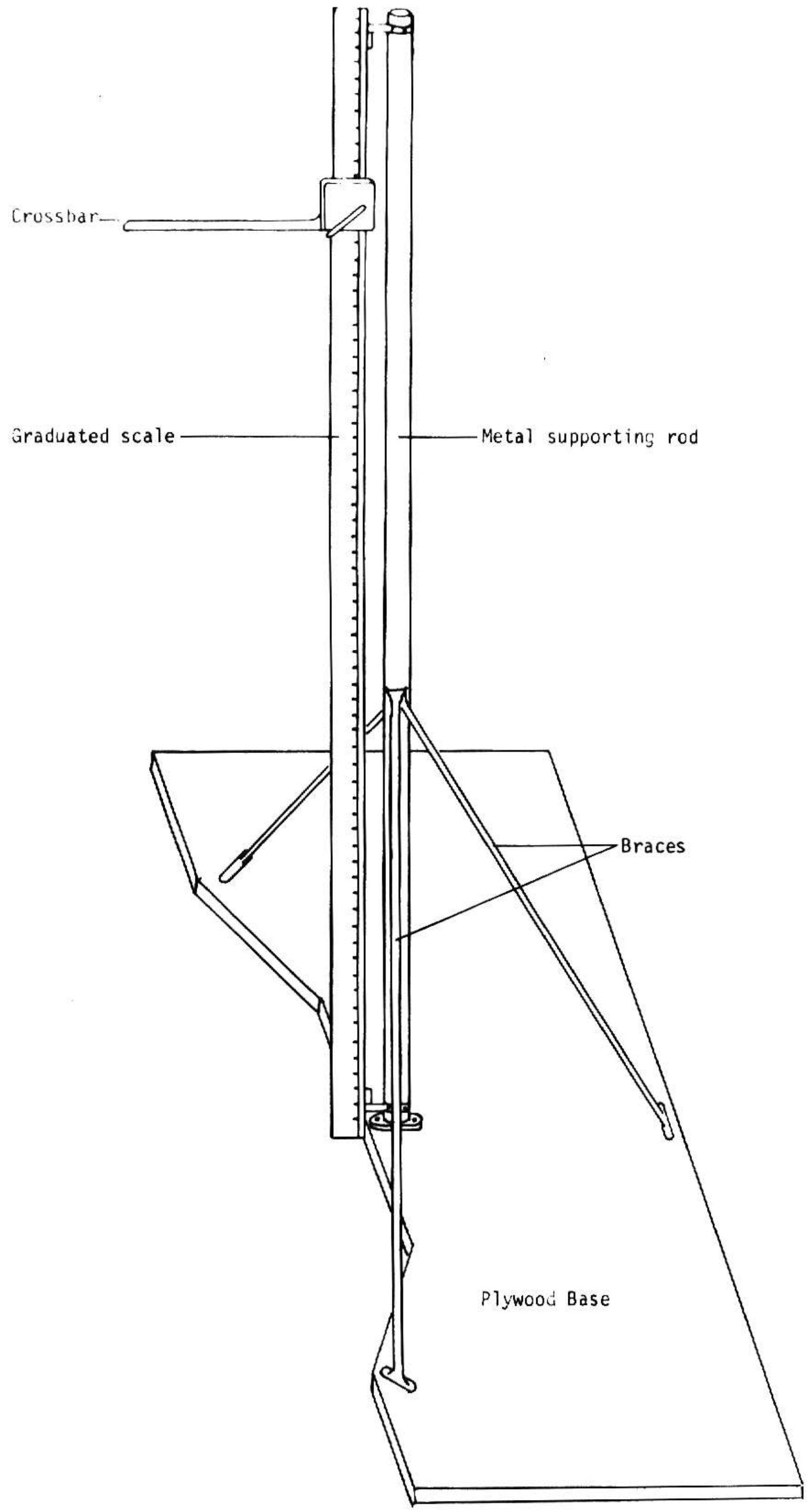

Figure 2. Anthropometer.

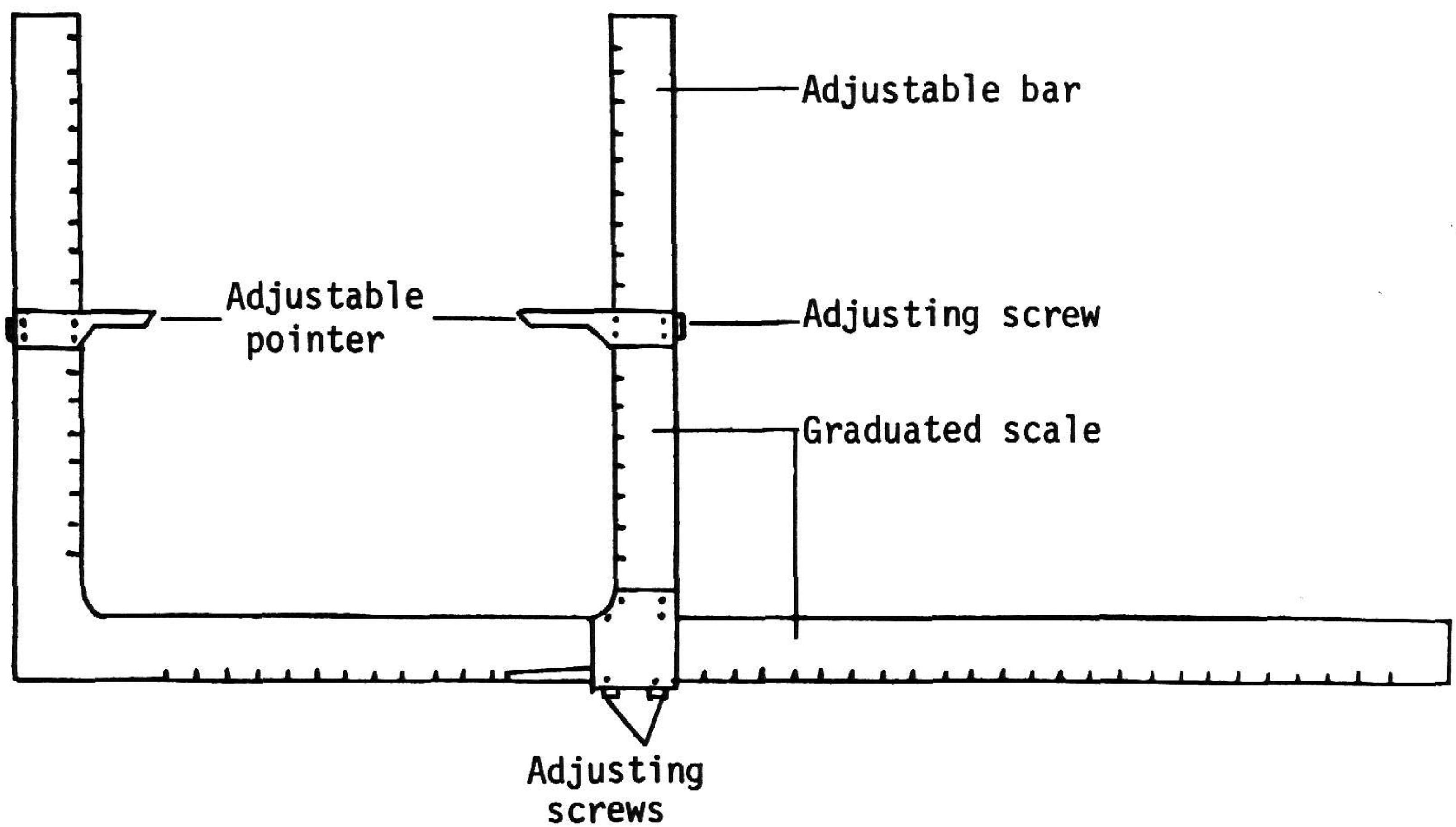

Figure 3. Sliding caliper.

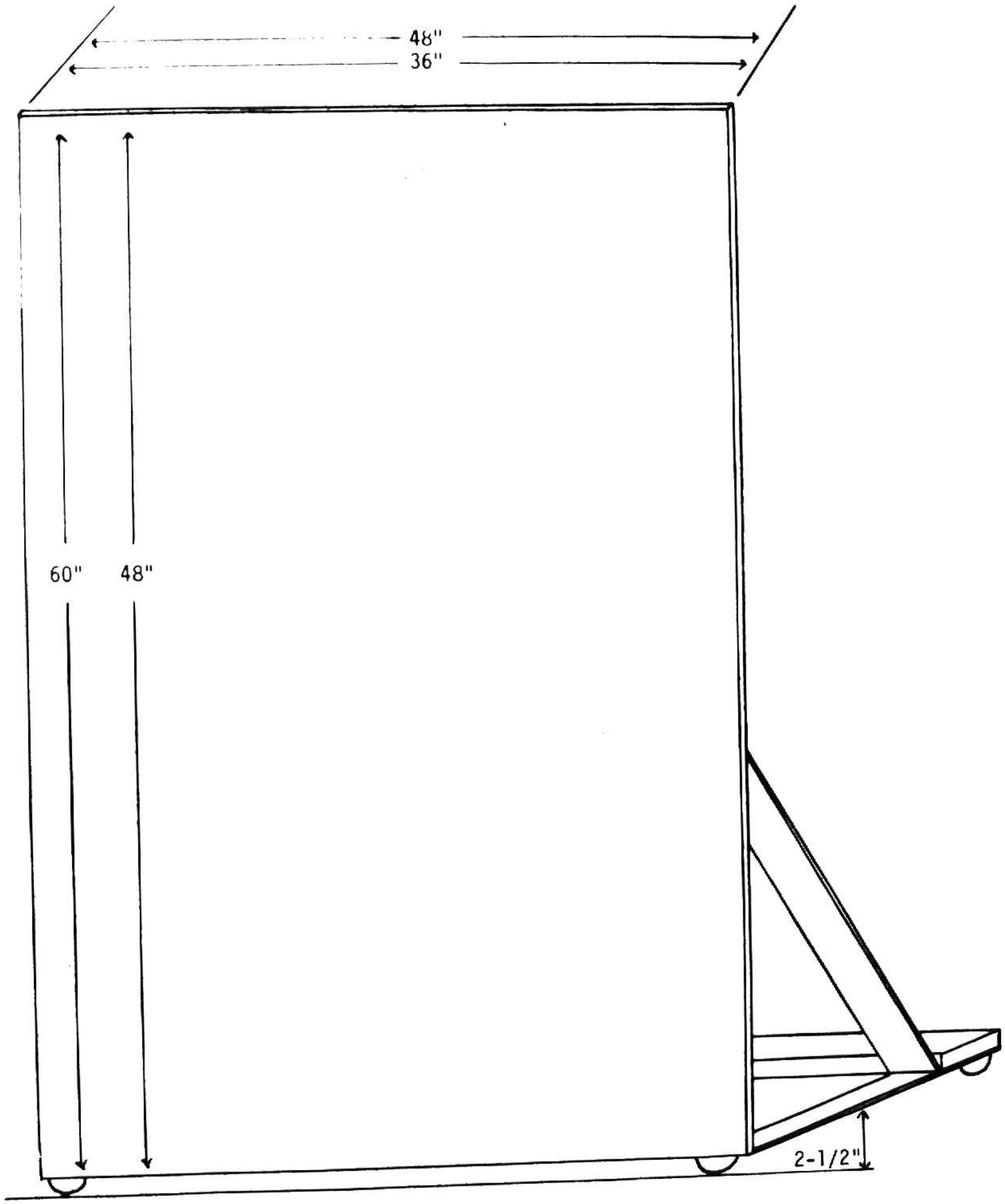

Figure 4. McCullough type movable wall, front view.

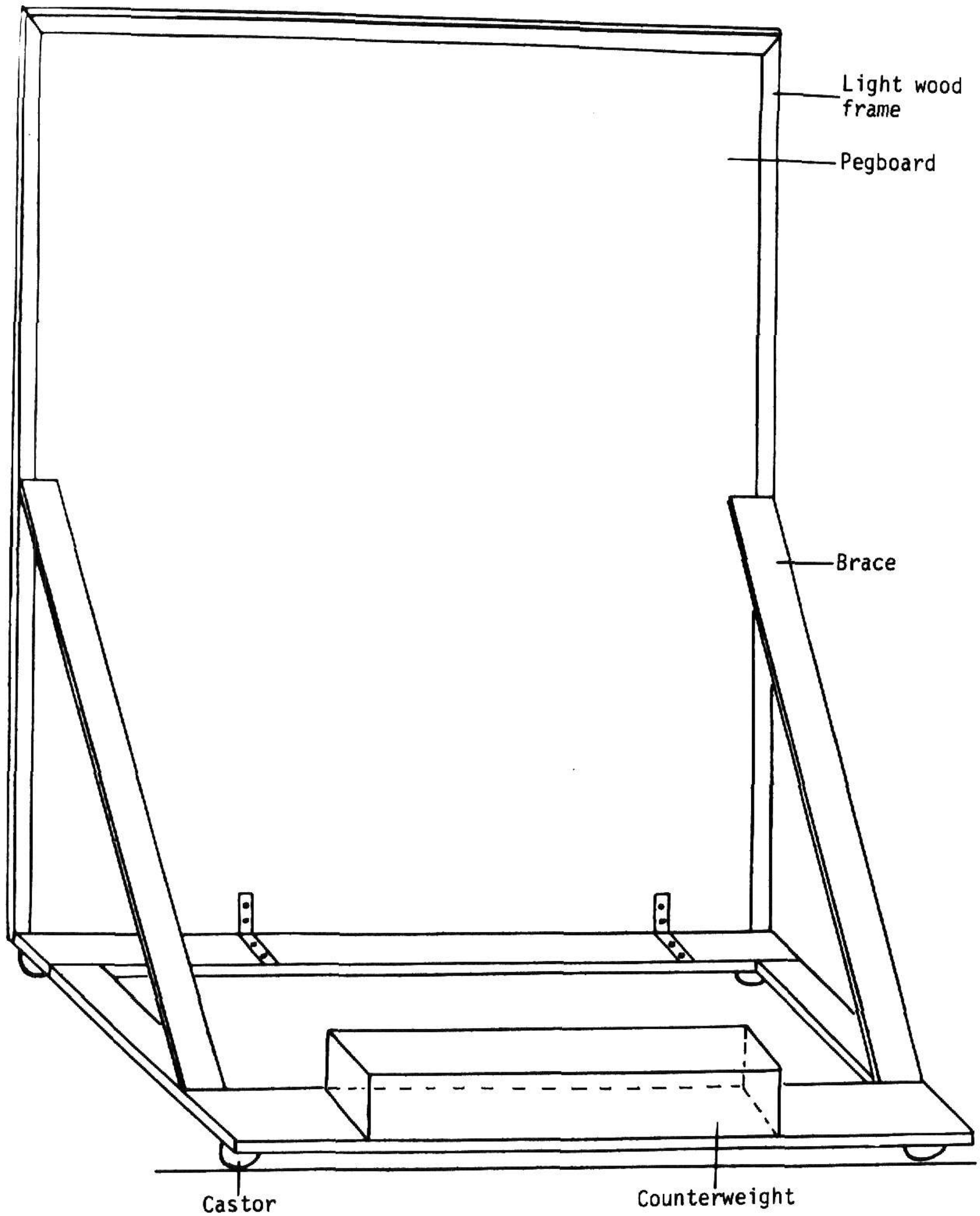

Figure 5. McCullough type movable wall, rear view.

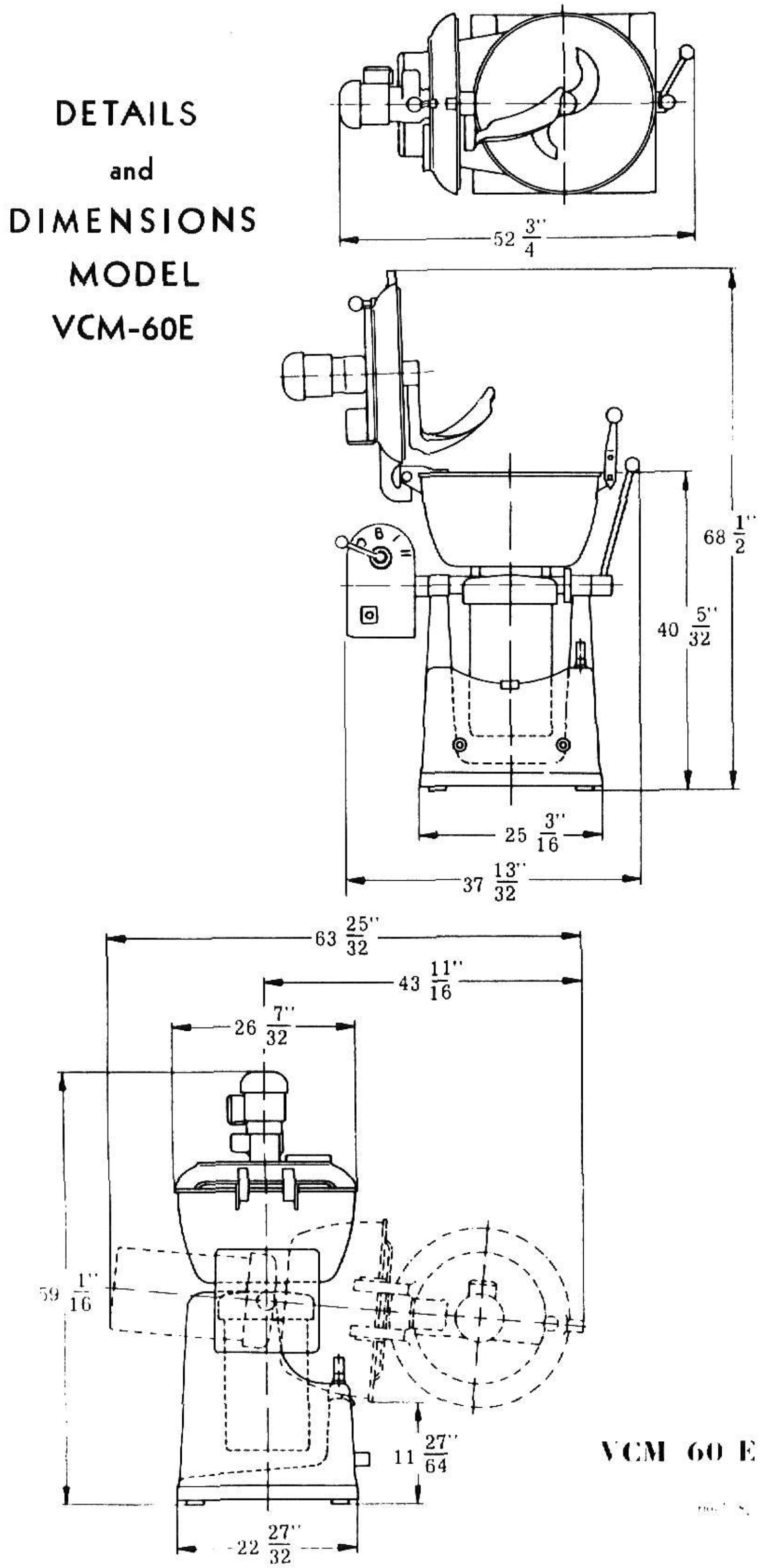

Figure 6. Dimensions of vertical cutter/mixer. Specifications from Hobart Manufacturing Company.

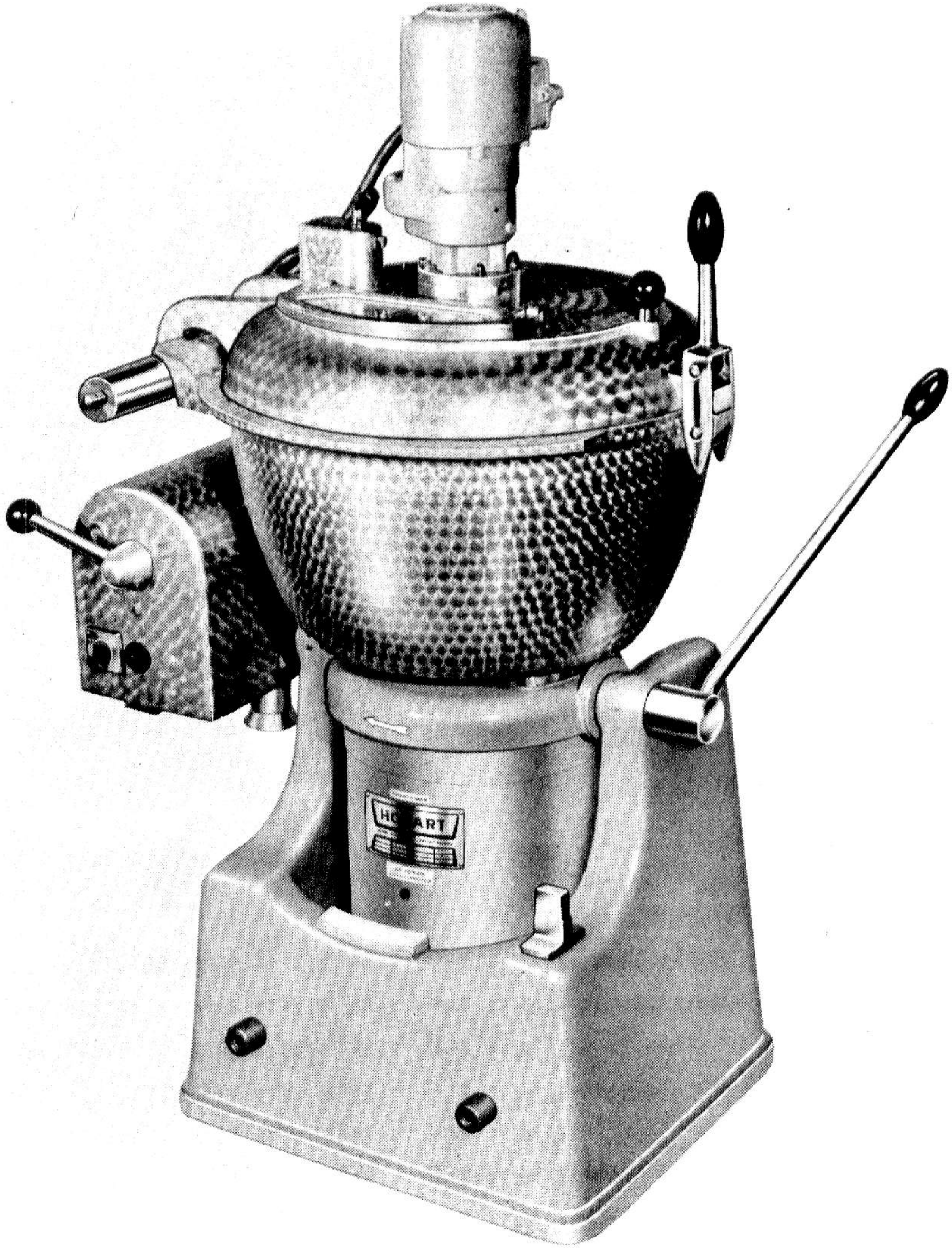

Figure 7. Hobart Vertical Cutter/Mixer Model 60E.

APPENDIX B

Anthropometric Data

Data Form

Name______________________ Age_____years Date______________

Address________________________________ Weight_________lbs.

Height

Standing

1. Stature ______ in.
2. Eye ______ in.
3. Shoulder ______ in.
4. Elbow ______ in.
5. Knuckle ______ in.
6. Arm Reach ______ in.

Breadth

7. Chest Breadth ______ in.
8. Hip Breadth ______ in.
9. Maximum Body Breadth ______ in.

Depth

10. Chest Depth ______ in.
11. Buttock Depth ______ in.
12. Maximum Body Depth ______ in.

1. Anthropometric Data Form

TEST ACTIVITY DATA

Name________________	Distance from center across (L)	Distance from center front (D)
1. Walls in		
2. Walls in		
3. Walls out		
4. Walls out		

Observations:

2. Test Activity Data Form

THE HUMAN BODY IN RELATION TO SPACE NEEDS OF FOOD SERVICE EQUIPMENT

by

HELEN ENSIGN MCMANIS

B. S., Kansas State University, 1941

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

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A relationship exists between space provided for food service workers who use equipment and effective operation. The performance may be jeopardized if a few inches critical to the operator is not provided. Since man cannot be changed, his dimensions, capabilities and limitations form the basis to improve system efficiency.

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2. To study the space needs of the same food service workers using a vertical cutter/mixer.

Anthropometric data included height, weight, body breadth, body depth, arm reach, shoulder height and hip breadth.

The activity test consisted of placing twelve heads of lettuce in the vertical cutter/mixer, moving to the switch box, turning the machine on then off, and opening the machine lid. Movable wall panels were placed close to the worker and adjusted as the result of the subject's body movements until maximum dimensions were made. The distance between the center of the machine and wall panels was measured.

The influencing factor for the amount of space used appeared to be body movements rather than body dimensions. Subject F, tallest in height, 64.5 inches, with one of the longer arm reaches of 33.24 inches, and weighing 141 pounds (overall 55th percentile) used less space than subject A, shortest in height, 57.8 inches, with one of the shortest arm reaches of 29.0 inches and weighing 130.5 pounds (overall 47th percentile).

Subject D, with smallest maximum body depth of 9.8 inches and maximum body breadth of 16.3 inches, required (1,089.43 square inches) more space to operate the machine than subjects A, E, F, and G, all with larger maximum body depth and breadth measurements.

No one measurement showed a significant correlation to the square inches needed for operation of a vertical cutter/mixer. A multiple regression of the measurements of eye, elbow, knuckle, hip, buttock and maximum depth to the "area in" and "area out" showed no significant correlation.

To establish space standards for the use of a vertical cutter/mixer, further work of a larger sample of subjects is recommended. Data from this study suggests rather than precise formulas which might be universally applicable, that a range of human dimensions be studied and the upper 95th percentile of food service workers be accommodated.