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AN ERGONOMIC STUDY OF APARTMENT KITCHEN WORK SPACE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

AN ERGONOMIC STUDY OF APARTMENT KITCHEN WORK SPACE

CHAPTER I

INTRODUCTION

For about twenty years, the architectural/construction industry has been on the brink of a revolution in kitchen design. Many articles and books have been published espousing the ergonomics aspects of work space design as applied to industry and the home. Unfortunately, the homemaker usually waits while innovative ideas for work areas are incorporated into the assembly lines, which tends to be a long, tedious process. There are at least two reasons for this apparent neglect: first, the homemaker is often oblivious to the design problems and second, it is not an easy task to convince manufacturers to change designs based on ergonomic data unless consumer opinion warrants such a change.

The time is appropriate for a transformation. Apartment and condominium living is on the rise and the designs are generally poor, particularly in the mass-produced, standard kitchens. In Norman, Oklahoma, for instance, there has been a significant increase (well over

100%) in "luxury, garden apartment" units in the past few years. Furthermore, women are becoming more involved in careers outside the home; consequently, more kitchen work for men is probable in the future. But today, kitchen design standards are for a 5'5" (plus or minus two or three inches) woman; how can a 6'2" man function efficiently in the same environment as his wife, a foot shorter? The answer is flexibility and adjustability in kitchen design which is the subject of this paper.

Apartment living is particularly appealing not only to single people but to young married couples with no children or very young children as well as to older couples whose children are no longer dependents. For the most part, these are the types of people for whom apartments must be designed, although in large cities apartments are the predominant living quarters for all people. Unfortunately, the kitchen work place generally suffers when architects and builders are designing and constructing large apartment complexes. In many apartments, the kitchen appears to be an afterthought, stuck in some "cubby-hole," or integrated to the extent that there is a constant flow of traffic through the work area. Granted, there are size limitations not experienced in houses, but with the proper application of ergonomics principles, the available space can be better used than it has been to date.

The kitchen is a work place. As such, it deserves the same attention to detail as any factory assembly line or research facility. Kitchens should be built with the housewife in mind by making her chores easier and more pleasant, saving her steps where possible, and giving her sufficient work areas and storage space. The ideal way to design a kitchen is to make it fit the specific person who is going to use it. This is only practical if you are building your own house. Generally, the anthropometric data available can be used to ensure a kitchen design agreeable to <u>most</u> women, but this is not much consolation to the 4'11" woman or 6'4" man trying to create a culinary masterpiece.

The emphasis of this paper is the location and height of kitchen counter space. The next chapter takes a cursory look at the history of the kitchen work place and some of the factors to consider in designing an efficient kitchen. Problems of a "standard" design are identified. Basic design principles that have been documented but ignored for years are listed. The need for awareness of the apartment dweller's likes and dislikes is stressed as well as the need for educating the populace to know what is physiologically best for each individual.

Chapter III presents the results and analysis of a survey of eleven Norman, Oklahoma, and San Antonio, Texas, apartment complexes. The parameters of interest here are the amount and location of counter space and the work triangle, an indicator of overall kitchen size and efficiency.

No attempt is made to establish new guidelines for counter space as existing ones are adequate if used properly.

Chapter IV describes an experiment to determine the effects of counter height on a woman's cardiovascular system for a typical mixing task. Eight women of various heights participated; the data consist of heart rate measurements versus two different counter heights. An analysis of variance is used to reduce the data to some quantitative conclusions and qualitative observations.

The economics of adjustable counter height is the subject of Chapter V. After all, it does not matter how much experimental data proves a certain design is not optimum if no one is willing or able to pay for the change. A few possibilities for counter adjustment are discussed with associated cost estimates for mass-producing a "new" base cabinet design versus the current, standard cabinets. The critical question is: "what effect would the recommended designs have on the average monthly apartment rental?" If the answer is anything but none or insignificant (a few cents), it will be difficult to sell a new design unless apartment dwellers are educated to the point where they will demand a change.

The final chapter summarizes the current trends in apartment kitchen design and suggests recommendations for a change in direction. The last few paragraphs identify some areas where more work is needed in applying ergonomic principles to the design of apartment kitchens of the future.

CHAPTER II

BACKGROUND

Quite possibly, the first time a prehistoric man knocked a hole in the roof of his cave to release the accumulated smoke from his fire marked the beginning of human engineering in the kitchen. In any event, kitchen design principles for many years have stressed improvement of the kitchen worker's efficiency and reduction of the human energy requirement. Kirkpatrick (1958) states these objectives differently: save the homemaker steps and decrease hours of work in the kitchen. Perhaps both these objectives for kitchen design are remiss in that satisfying them does not necessarily remove the fatigue and discomfort component caused by too low or too high counters, sinks, ovens, etc. Bratton (1959) has suggested that energy cost is probably not the most important factor in the fatigue of standing. Anyone who has stood at attention or even at ease for prolonged periods will recall some amount of fatigue. The next logical step is to specify three key considerations for designers to heed in kitchen planning: efficiency or time saving, energy or step saving, and fatigue.

Unfortunately, many excellent ergonomic design principles have never found their way into the architect's or builder's scheme of home construction. Too often, the kitchen has been neglected and relegated to anonymith as an essential room but not necessarily an aesthetic one at least from a human engineering viewpoint. This is particularly true in apartments where the kitchen more often than not emerges as a hastily designed nook to fill in the extra space between the living and bed rooms.

The importance of the kitchen has fluctuated through the years. In colonial times, the kitchen, often the only heated area, was the center of the household. There were few labor saving devices, and as the fire was on the floor, the woman did most of her cooking bent over at the waist. Even so, the kitchen tasks were relatively easy compared to other tasks at the time.

By the middle of the 18th century, the discomfort of cooking was relieved somewhat by the advent of wood and coal burning ranges with a higher heat surface and protection from open flame. The rise of urban America caused a decline in the importance of the kitchen in the 19th century. Individual family members became more independent and the kitchen was relegated to an isolated area for cooking only. Beyer (1953) suggests the place of rural kitchens in family life did not fluctuate so dramatically with the times. Rural citizens have generally accepted new technology more slowly and retained the family-oriented kitchen.

The urban woman continued her liberation movement into the 20th century, and functional kitchens were born. These kitchens were long and narrow to make use of maximum space and were built for convenience and aesthetic appeal. By the 1920's, though, the homemaker no longer wanted to be isolated, and the cycle returned to an integrated kitchen/dining room area with a large enough kitchen for social activity. This trend continued through the 1950's.

Today, as is the case in many facets of our society, anything goes. The women's liberation movement has made its impact on the kitchen design outlook for the future, i.e., more compact, step-saving, more efficient use of space, and lesser demands on time and energy. The impact may manifest itself in at least two ways: the married woman with an outside career may want the kitchen to be an isolated food preparation room; the married woman at home will probably want a more socially-oriented kitchen to satisfy her entertainment and home management requirements. In both cases, the husband will probably be working in the kitchen more often than in the past. Physical conveniences and aesthetics, such as lighting, color, and the flow of built-in equipment and cabinets, reach different levels of importance for different women. In any case, kitchens of the future will probably find the man more active in food preparation and clean-up. This must be taken into account when designing "standard" equipment and cabinets.

Many books and pamphlets have been published on the art of kitchen design. Perhaps the most significant contribution is the 1953 publication, <u>The Cornell Kitchen</u>, which summarized the design guides known at that time and presented a modularly constructed kitchen which has influenced design in the past twenty years. <u>The Cornell Kitchen</u> discusses all the psychological and physical aspects of kitchen design from homemaker motivation to types of materials used in building cabinets. Of primary interest is the motivation/energy relationship: the desire to work is proportional to the amount of energy made available. Since kitchen work is often repetitive and routine, it is extremely important to provide the homemaker with a favorable attitude by making her comfortable in her work; organizing supplies, equipment, and work areas; appealing to the senses with the proper use of color, lighting, sound, temperature/humidity, surface textures and lines, shapes, etc.; and recognizing the importance of rest and the feeling of accomplishment in preparing a first rate meal.

The Cornell study suggests kitchen design for specific individuals which is ideal. Unfortunately, mass construction of housing and apartments obviates personalized design. Granted, if you buy a house, you can alter the design to fit your needs, likes, or conveniences. But most families cannot afford such a luxury and, if they could, would probably have the house built for them from their own blueprints. Apartment dwellers, on the other hand, do not have an option to physically alter their home. They cannot even change the wall coloring, which is the least a house owner could do. Consequently, apartments are designed with no particular individual in mind, since bachelors, young married couples, families, or retired couples could live in a given apartment over its life cycle.

Since "standard" apartment kitchens generally use 36 inch counter heights, one major problem is obvious. A 4'11" woman could live in the apartment one year, a 5'6" woman the next, and a 6'3" man the third year. Even disregarding the "different work heights for different tasks" concept, the short woman and tall man would find it extremely uncomfortable using these counters. More critical, at least for the tall person, is the sink, whose bowl is normally at a height of 29 to 30 inches or 6 to 7 inches below counter level. Dishwashing is a considerable chore for a six foot person primarily because of the static loading on the lower back. In fact, male or female back problems, which are not uncommon, will be aggravated at the least if the worker uses counter tops that are not adjusted to the appropriate height. It is difficult to judge the contribution of standard kitchen design to the back problems of homemakers because normally the effect would show only over a period of years and could not be noted in a simple experiment. Even so, current electromyographic techniques (the measure of electric phenomena during muscle contraction) could be used to measure the muscular activity of the lower back and thigh region in particular. The data may be helpful in determining the strain on the back from three to four hours of daily kitchen work. As mentioned earlier, kitchen tasks are not difficult from a metabolic standpoint, but the static loading on the worker, particularly those who do not happen to be between 5'3" and 5'8" tall, plays an important role that is often overlooked.

The following were proposed by Child (1916) as basic principles of kitchen efficiency:

1. Keep nothing in the kitchen that is not used every day.
2. Things used oftenest should be most conveniently near at hand.
3. Grouping of utensils and supplies should be governed by the principle of coordination of processes.
4. Have narrow shelves with one row of things on each.
5. Use open shelves rather than cupboards and closed closets.
6. Shelves should be at a convenient height, none lower than 12 inches nor higher than can be easily reached.
7. Nothing should be permitted to rest on the floor. This saves bending over and facilitates cleaning.
8. Have nothing in the kitchen that is not easy to clean.
9. Fixed equipment should be placed where the light is good.
10. Floor covering should be easy to keep clean and pleasant for the feet to rest on.
11. Small utensils should be suspended from hooks and cup-hooks fastened to the wall or the edge of shelves.
12. Sink and work table should be at a convenient height for the worker.
13. There should be a special place for each thing used in the kitchen.

Although the principles are generally just as applicable today, rare is the person, architect or homeowner who takes advantage of more than half of them. The Cornell Kitchen more or less iterated these principles and modernized them with the accent on ergonomic considerations. The following guides proposed by Beyer (1953) are as good today as they were twenty years ago; yet, they are ignored for the most part by equipment and cabinet builders and kitchen architects:

1. Minimize reaching, stooping and walking.
2. Limit reaching height to that a woman can reach with bent fingers and both feet flat on the floor in a comfortable working position.
3. Arrange storage space so that items are located close to where they are first used.
4. Frequently used items should be stored where they can be taken down or put back without excessive strain.
5. Items should be stored so that they may be easily seen, reached and readily grasped.
6. Storage space should be flexible to permit adjustment to varying sizes, amounts and kinds of stuff.
7. Location of work surfaces should not be such as to require uncomfortable working posture.
8. Worker should be able to sit if she wishes at certain areas such as the sink and mix center.
9. Counter work surfaces should be adjustable to different heights.

There has been much disagreement in translating ergonomic design principles into building specifications although, as Grandjean (1970) opines, there is no reason why the aesthetics of engineering design or "functionalism" in architecture cannot find expression in the application of ergonomic principles. Principle 12, as proposed by Child, is the one of most interest in this paper. Anthropometric data and individual preference have been the predominant criteria in determining work suface heights.

Counter heights are discussed in detail in Chapter IV. The ninth Cornell guideline is most appropriate here, although seven and eight are related. Even with the considerable emphasis placed on counter height twenty years ago, the standard remains at 36 inches, owing its survival more to appearance than suitability. The streamlined kitchen may look nice, but if all the working surfaces (including heating elements and the rim of the sink) are uniform, then the kitchen has not been designed for efficiency in the manner a factory assembly would be designed.

The lack of public recognition of the desirability of adjustable counter heights, ideally suited for apartments or mass-produced housing, or at least two or three different fixed work area heights can be partly attributed to the dozens of home improvement magazines and home builders and buyers guides that have proliferated through the years. Generally, the people who write these books and magazine articles are more attuned to the aesthetic features of a kitchen and not knowledgeable or concerned with the ergonomics aspects. Of course, many of the good design principles have become standard, but unfortunately the "standard" often is arbitrarily altered until it is no longer visible. For example, the work triangle concept is generally accepted but is void when the dimensions of the triangle are set arbitrarily and the flow of traffic is through the middle of the triangle. The work triangle is defined as the sum of the distances between the sink, refrigerator and range and is discussed further in the next chapter.

After completing her study of ironing heights, Knowles (1946) concluded that the homemaker should be most concerned with two things: an awareness of needs and adjustable height equipment for major tasks. "Awareness of needs" is perhaps the key phrase in human engineering design. Most people are not aware of the subtleties of man-machine design and do not realize that the cause of their excessive fatigue or backaches may be a direct result of the work place design. Counter heights have been at 36 inches for so long that people have become accustomed to the "standard" and naturally assume it is sufficient and unchangeable. Given an opportunity to try other counter heights or ironing heights, many people have been surprised at the difference three to four inches can make. Shorter people notice a decrease in fatigue and tension of the shoulders which is characteristic of working at too high a counter, where the shoulders are lifted and the elbow is bent and abducted from the body. Taller people notice that the "standard" counter causes them to stoop while working, which tires the back and leg muscles.

The relative obscurity of the counter height problem is definitely not shared with that of counter space or frontage. All housewives, "househusbands," and many single persons are acutely aware of the amount of counter space in their kitchens. In an apartment, the lack of such space is particularly annoying when entertaining guests. How many times has a woman called on her husband, children, or guests to hold a platter or bowl until she made room for it on the counter? How often is the setting of the table delayed until the last minute because the table is an essential addition to the counter space? Any man who has prepared a four course meal in a typical, tiny apartment kitchen can appreciate his wife's not enjoying the idea of dinner guests and perhaps can understand why she likes to dine out so often.

Once again, there are many sources of guidelines for the amount of kitchen counterspace. The Illinois Small Homes Council, United States Department of Agriculture (USDA), and many architects publish books and pamphlets for public use in designing counter space into kitchens. Why this information is not used more often, or perhaps used too freely at times, is a mystery. Contractors will often state economics as the reason for cutting corners, but more often than not a properly designed kitchen layout will be no more expensive than the "economic" one. At least one architect, Bolton (1965), has recognized the importance of counter height by stating he sees no reason for a standardized 36 inch counter. Even USDA (1957) and the Small Homes Council (1965) use standard modular counters in their recommendations. Of course, the reason for this is clear: most people using

USDA or other such planning guides probably cannot afford or have a low priority for customized counters. The solution, then, is to market standard counters (base cabinet modules) with adjustable counter heights. Chapters IV and V explore this idea in detail.

CHAPTER III

APARTMENT KITCHEN SURVEY

The first step in this study of apartment kitchens consisted of a survey of various apartment complexes in Norman, Oklahoma, and San Antonio, Texas. Some accepted guidelines for kitchen counter layout and criteria for evaluating a kitchen work place will be discussed prior to the survey results and analysis. The criteria will be used against the kitchens surveyed for an indication of a trend in apartment kitchen design.

For years, the number one criterion for kitchen evaluation has been based on the three major kitchen appliances: refrigerator, range, and sink. According to the criterion, these appliances must be situated in some sort of triangular arrangement, hence the concept of a "work triangle." Parallel-wall, U-shape, and L-shape kitchens are the predominant traditional designs. In the first, two major appliances are located along one wall while the third would be along the opposite wall. In the second, one appliance would be located on each of three walls. The third layout is like the first except the two walls are adjacent rather than opposite. As Figures 1 and 2 show, all three plans are based

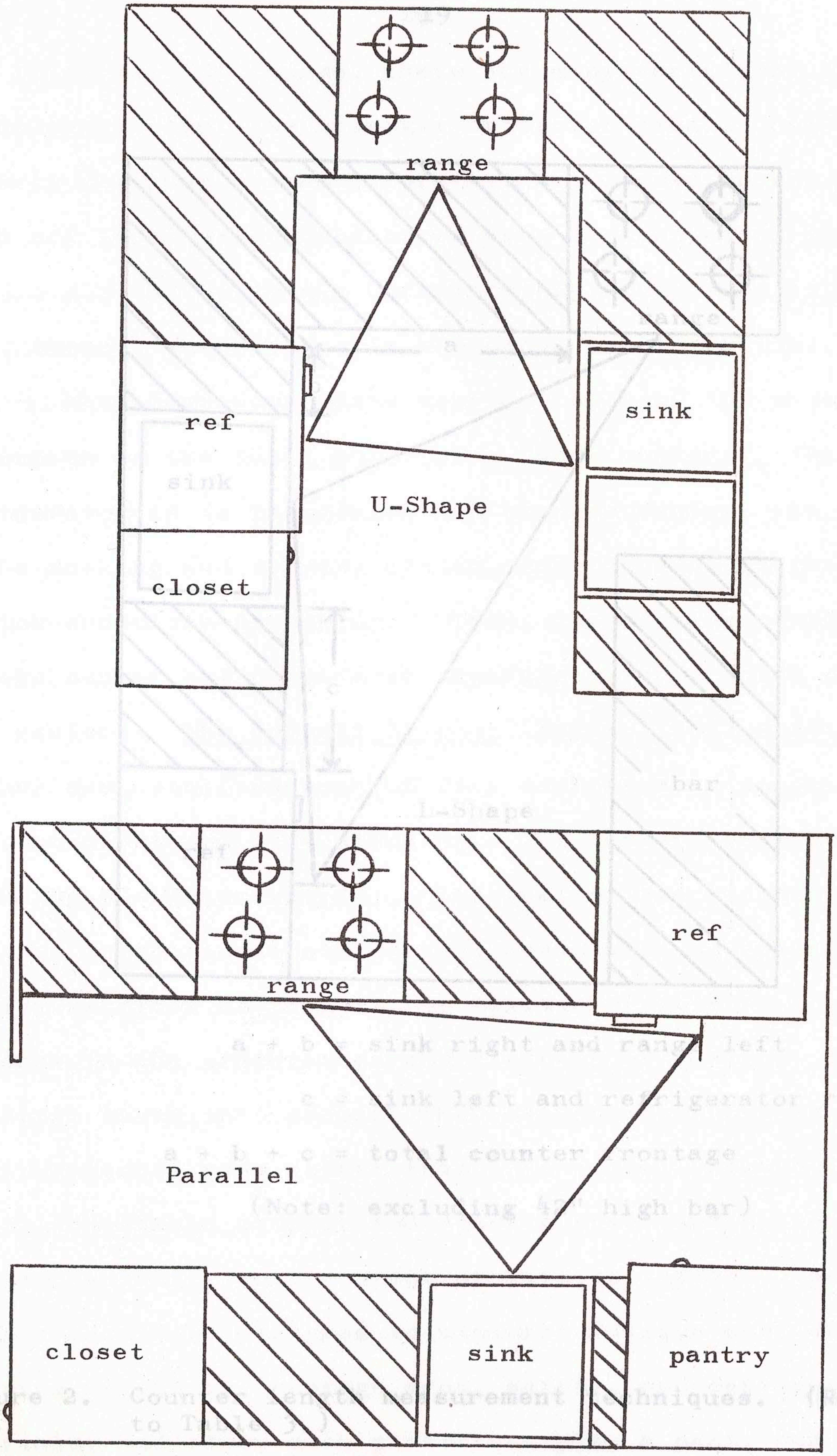
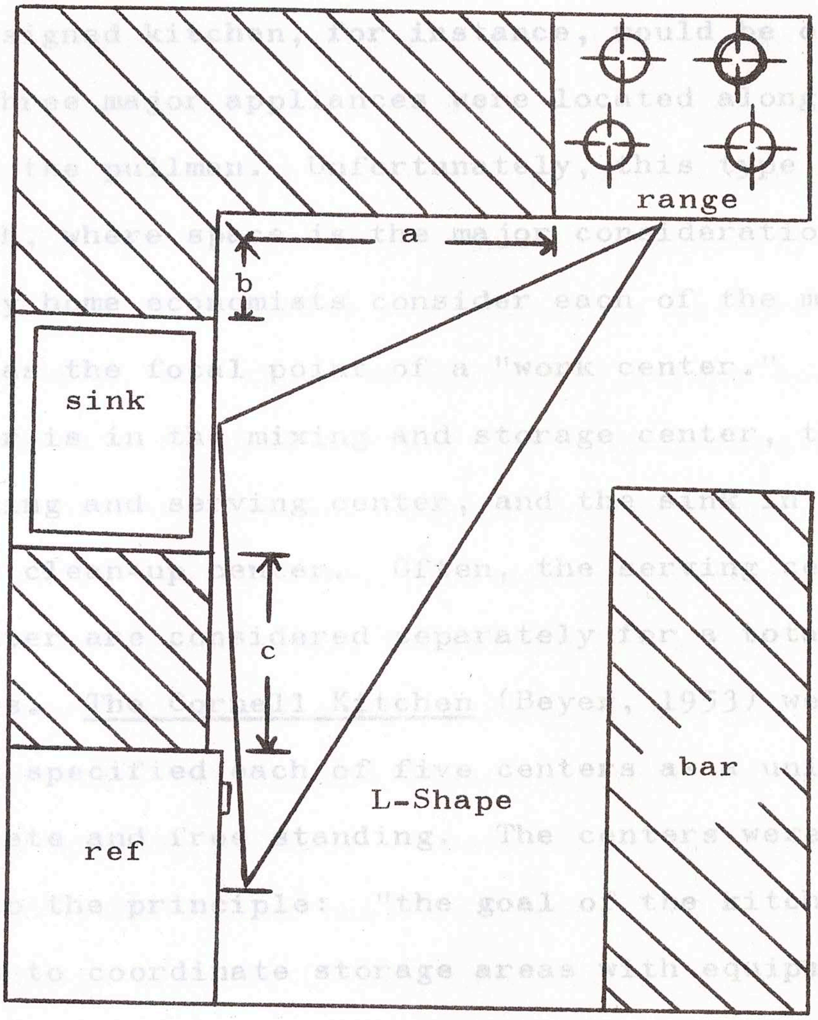


Figure 1. Typical apartment kitchen layouts.



a + b = sink right and range left

c = sink left and refrigerator right

a + b + c = total counter frontage

(Note: excluding 42" high bar)

Figure 2. Counter length measurement techniques. (Refer to Table 3.)

on a triangle. Of course, there are many variations of these layouts, but the triangle criterion usually holds true. A poorly designed kitchen, for instance, would be one in which all three major appliances were located along the same wall, i.e., the pullman. Unfortunately, this type is necessary, though, where space is the major consideration.

Many home economists consider each of the major appliances as the focal point of a "work center." The refrigerator is in the mixing and storage center, the range in the cooking and serving center, and the sink in the preparation and clean-up center. Often, the serving center and storage center are considered separately for a total of five centers. The Cornell Kitchen (Beyer, 1953) went even further and specified each of five centers as a unique unit, complete and free standing. The centers were designed according to the principle: "the goal of the kitchen designer is to coordinate storage areas with equipment and utility services as to give the maximum efficiency to work patterns in the preparation and clean-up of meals." This principle takes into account the idea of a kitchen as a family-oriented room rather than just a meal preparation area. Adjustable storage and counter space and height stress the family work concept of kitchen design. The work centers should be designed to minimize fatigue and boredom. Coloring, lighting, storage area, safety, and construction materials, and other such parameters play a part, but only the counter space and individual work center heights will be addressed in this paper.

For simplicity, further discussion of the work triangle will be confined to three work centers as previously defined. This limitation is more appropriate for apartment kitchens where space is at a premium and generally there is no practical way to separate mix and serve centers from the storage, cooking, and clean-up centers. Before continuing, it is appropriate to mention that the work triangle philosophy will not necessarily continue to dominate the scene in the future as it has to date. The island kitchen complex has received much exposure. Seney and Young (1970) described a "core concept" in which compact appliances, microwave ovens, and mobile serving and clean-up carts are built into a five by seven foot island. Others visualize work centers pivoting on butcher block tables (Habeeb, 1970) or based on large storage lockers ("The Super Kitchen," 1970). Even more advanced are modular groupings with computer center support (Spencer, 1970), perhaps via a remote terminal to a time-shared central processor on a monthly rental basis like other utilities. The compact modules would be designed for easy mobility to allow the worker flexibility in work center arrangement. Of course, all storage space and counter heights would be adjustable and appliances would be readily accessible, i.e., no bending to use the oven or dishwasher or sink.

There is considerable latitude in planning the work triangle or "vital triangle" as Spencer (1971) has named it. Generally, the length of the work triangle, defined as the sum of the distances between the center front of the sink, range, and refrigerator, should be no less than 14 feet and no greater than 23 feet. Each individual leg should be between 4'6" and 7'6" and is dependent on the layout used. The counter space is of particular interest and is at least partially defined by the legs of the work triangle. It is obvious that a kitchen with a 23 foot work triangle will most likely have more counter space than one with a 14 foot triangle; if not, you can be assured there is much wasted space. A major problem is that of "slick kitchen uniformity," a phrase coined by Gutheim (1948). A kitchen with even surfaces throughout may be aesthetically appealing but certainly is not work oriented. For instance, if the rim of the sink is lined up with the counter top, then the sink is at least six inches too low. If the cooking surface of the range is at the correct height, then the oven is too low, assuming a traditional combined oven/cooktop.

The recommended counter space for kitchens is well-documented for houses but not much has been written on the unique problems of apartments. The standards published by the Illinois Small Homes Council (Kapple, 1965) are used in many of the home economics texts and magazines. The Council bases its recommendations on the size of the house with three different sets of standards listed for houses less than 1,000 square feet, greater than 1,400 square feet, and those within that range. The following discussion will be limited to the under 1,000 square feet recommendations, since the apartments surveyed were about 700 to 900 square feet. The United States Department of Agriculture (1957) and _Architectural Graphic Standards_ by Ramsey and Sleeper (1965) recommend considerably more counter space but they are primarily concerned with larger homes and not apartments. The Small Homes Council recommendations for homes over 1,400 square feet are more in line with USDA (over 110 inches of total counter frontage, for example).

The Small Homes Council standards for counter frontage, defined as the counter space accessible to the worker, are shown in Table 1. The inaccessible space in corners is not included in the recommendations. Furthermore, the counter frontage on both sides of a corner is included in determining the frontage serving appliances on either side of the corner; Figure 2 illustrates the application of the measurement techniques. The numbers given in Table 1 are considered optimum; a larger kitchen may be a poor use of space in an apartment, but a smaller kitchen may be inadequate. Of course, the number of people living in the apartment has a bearing on the amount of storage and counter space considered adequate. The apartments surveyed were optimally sized for two or four people. Even so, these recommendations should not be taken as gospel. Many other factors, such as the hours spent preparing meals or baking, all impact on the appropriate kitchen size.

TABLE 1

SMALL HOMES COUNCIL RECOMMENDATIONS FOR COUNTER FRONTAGE, HOMES LESS THAN 1,000 SQUARE FEET

Location	Counter Frontage (inches)
Right of the sink bowl*	24
Left of the sink bowl*	18
Adjacent to latch side of refrigerator	15
Either side of range or built-in cooktop	15
Either side of oven	15
Mixing area	36
Total amount of counter frontage	72

*Assumes a left to right dishwashing sequence.

SOURCE: Kapple, 1965.

The most critical counter space is on either side of the sink. Every effort should be made to ensure enough space here, but other locations can be adjusted somewhat to satisfy space requirements. In most kitchens, counters will serve more than one appliance, hence the reason that the sum of the individual recommendations does not equal the total amount recommended (Table 1). Whenever two or more counters are combined, a good guideline is to use the longest counter length plus one foot providing the total frontage is not less than recommended (Kapple, 1965). For instance, Figure 2 shows a typical L-shaped kitchen which meets the counter frontage specifications.

Some authors, such as Peet (1970), apply the work triangle concept and counter frontage standards to both traditional designs, such as the U-shape, and contemporary designs with islands and other than 90 degree corners but loosely based on the traditional. The same techniques can be applied to futuristic designs, although the work triangle may be warped. In any case, as long as people enjoy eating home-cooked meals, sufficient counter space must be a prerequisite for kitchen design.

Now that the guidelines have been presented, their application in actual contemporary apartment construction can be explored. The data in Tables 2 and 3 were collected from seven garden apartment complexes in Norman and four in San Antonio. All the apartments were generally the same size with two bedrooms, a living room, kitchen, dinette, and bath (two baths in two cases). Rentals in 1974 ranged from $160 to $260 per month with San Antonio about $20 higher than Norman for an equivalent apartment. All but two of the apartments were constructed in the past five years. Rather unexpectedly, the best overall kitchen was found in one of the two older apartments. It is interesting

TABLE 2

WORK TRIANGLE DATA--DISTANCES BETWEEN THE CENTERS OF THE MAJOR APPLIANCES

Apartment Identifier	Kitchen Type	Sink to Range	Sink to Ref	Range to Ref	Total
Alpha	Parallel	7'1"	5'9"	4'6"	17'4"
Bravo	Parallel	3'4"	5'0"	3'6"	11'10"
Charlie	U-shape	3'5"	4'4"	5'4"	13'1"
Delta	Parallel	3'5"	3'10"	3'9"	11'0"
Echo	Parallel	5'3"	4'11"	4'8"	14'10"
Foxtrot	U-shape	3'11"	3'1"	3'6"	10'6"
Golf	L-shape	4'9"	5'6"	7'9"	18'0"
Hotel	Parallel	4'4"	4'1"	4'10"	13'3"
India	Parallel	4'2"	4'5"	4'0"	12'7"
Juliet	L-shape	4'2"	5'4"	7'10"	17'4"
Kilo	Parallel	4'10"	3'3"	3'10"	11'11"

Small Homes Council Standard--4'6" to 7'6" recommended between each pair of appliances with a total recommended work triangle of 14-23 feet.

TABLE 3

COUNTER LENGTH ADJACENT TO EACH APPLIANCE (INCHES)

Apartment Identifier	Sink Right	Sink Left	Range Right	Range Left	Ref Right	Ref Left	Total Frontage
Alpha	0	27	21	21*	21*	0	68
Bravo	22	33	12	12*	12*	0	79
Charlie	42*	29#	29#	0	0	42*	71
Delta	32	26	15*	15	0	15*	88
Echo	26	27	0	22*	22*	0	75
Foxtrot	14	30*	30*	29#	29#	0	73
Golf	53*	23#	0	53*	23#	0	76
Hotel	30	4	24*	23	0	24*	81
India	20	28	16*	14	0	16*	78
Juliet	30*	35#	35#	12	0	30*	77
Kilo	30	29	15*	0	0	15*	74

* and # represent appliances sharing common counters.

to note that with one exception (the most expensive apartment), there was no apparent relationship between rent and size/design of the kitchens. The differences in rental were primarily due to "extras," such as fireplaces, patios, washer/dryer connections, tennis courts, etc.

Table 2 lists the types of kitchens in the survey and the work triangle measurements. Seven of the kitchens are smaller than the suggested minimum. Even lowering the Small Homes Council standard to 12'6" still leaves out four kitchens, which is a poor average. The individual legs of the triangles follow suit. The most unexpected observation is a substandard work triangle distance does not mean there is a lack of counter space. Comparing Tables 2 and 3, the kitchens with the most counter frontage (Bravo, Delta, Hotel, and India) all fail to meet the work triangle standard. Yet, the kitchen with the least frontage (Alpha) easily meets the triangle standard. The paradox is explained simply in that Alpha has much wasted space between opposite walls; although the sink and refrigerator are opposite one another, there is seven feet of space between them. In the case of the other four kitchens, the working space between opposite counters is only three to four feet. Both situations are less than adequate. An optimal five feet, but no less than four and a half feet, should be provided between opposite counters or major appliances to allow two people to work comfortably without colliding continually.

The parallel-type kitchen is by far the most popular for the apartments in this survey at least, although the L-shape yields more working area and flexibility of design. The U-shape is generally recognized as best for houses but tends to be too small when put in an apartment. The parallel-type kitchen is more convenient when space restrictions are a factor, which explains its wide-spread use.

In comparing the data in Tables 1 and 3, it is seen that all the kitchens in the survey have sufficient total counter frontage (from 68 to 88 inches). Unfortunately, in most cases, the frontage is poorly located. Two (Alpha and Hotel) are severely handicapped by lack of counter space on one side of the sink. This may not seem important to those people who have become accustomed to a dishwashing or preparation/clean-up sequence with counters on both sides of the sink taken for granted, but it is inconvenient at the least and totally frustrating at times not to have counter space on both sides of the sink.

Another problem noted in the application of the standards is the tendency to limit common counter space between the range and refrigerator to 15 or so inches. As suggested previously, appliances sharing common counter frontage should use the longer recommended frontage plus one foot. In eight cases in Table 3, the range and refrigerator share a common counter, yet the frontage provided is sufficient in only four cases. Only three kitchens have the recommended counter frontage for a mixing area. Five others, though, have 30 or more inches of uninterrupted frontage which is probably sufficient in most cases. Under 30 inches is marginal at best.

It is easy to see what has been happening in apartment design. Architects and cabinet builders have attempted to provide sufficient total counter frontage but in doing so have not left sufficient uninterrupted counter frontage. The range, sink and refrigerator are so placed as to make kitchen work more difficult. With the addition of toasters, blenders, and other small appliances on these small counters, there is little room left for meal preparation. Consequently, all the utensils and supplies are spread over two or three different counters. To accomplish the simplest mixing task, the homemaker has to reach across the range or the sink.

Furthermore, all the counters in every kitchen are the standard 36 inch height. In some cases, a 30 inch high dining table is near enough to the kitchen to provide a mixing area. This is fine for everyday activities but inadequate for dinner parties when the table has to be set before the meal preparation is completed. In other cases, a bar, 40 or more inches high, is available for serving purposes but in only one case (Golf) is useful for meal preparation or receiving groceries and in fact could be included as counter frontage. The bar has not been included as frontage, though, since it is too high (42 inches) for most people to work comfortably.

The problem has been identified and analyzed, and the solution appears obvious. Architects and building contractors must be made aware of the problems existing today in apartment kitchens. Although there is a temporary slack period in the construction industry, the apartment building boom will no doubt continue in the future. Now is the time to reconsider the "standard" design and alter it to meet the needs of the apartment dweller and not the whims of the architect.

The next two chapters will take a closer look at counter heights with the emphasis on adjustibility and cost as an initial step in eliminating "slick kitchen uniformity."

CHAPTER IV

ERGONOMIC ASPECTS OF ADJUSTABLE COUNTERS

Thus far, many general statements directed against the idea of a standard counter height have been made. This seemingly hopeless battle has been waged for years, not only for variable counter heights but for adjustable ironing boards, tables, and storage areas. In some cases, there has been success.

Before Knowles' experiments with ironing heights, the following were typical examples of the "rules" for determining work surface height (Knowles, 1946):

1. Stand erect with the arms resting comfortably at your side, making a right angle at the elbow. Measure from the floor to the elbow at its lowest point and subtract 6 inches. This height is recommended for washing dishes in comfort. (Marion C. Bell, November 1927, N.J. State College of Agriculture Extension Bulletin No. 65.)
2. A working surface height equal to half the worker's height is good for practically any kind of kitchen work. (Marion R. Smith and F. E. Fogle, March 1925, Michigan Agricultural College Bulletin No. 37.)
3. If you can stand erect and place your palms flat on the table (without bending your back), the surface height should give the least strain while you are working. (Esther Warner, August 1920, University of Nebraska College of Agriculture Bulletin No. 60.)

Knowles began her experiment by testing these "rules." She found that poor posture and bending at the waist occurred at the work surfaces that should have been appropriate for the subjects. Although the "rules" are not generally suitable, they are still in use at times. For instance, Sunset Books (1967) uses a variation of the first rule as a "rough idea of the best counter height." We may surmise that the rules are still more appropriate than a standard surface height regardless of the task or worker's stature.

Knowles (1946) conducted some tests at various board heights. Each subject ironed on the standard, at that time, 31 inch board and also at a board set to the subject's preferred height, which was selected from anthropometric data as well as individual preference. The test results were as expected: the angle of bend at the waist of the test subjects while using the standard board was 5 to 77% greater than while using the preferred-height board; 5 to 50% more force was exerted on the standard board; and the subjects shifted their weight more while ironing at the standard board. The heart rate and blood pressure were measured and proved to be significantly higher (30% for heart rate) when the subject was ironing at the standard height. Knowles conceded it was difficult to establish criteria for determining the proper surface height, although she believed vision to be a factor. In her experiment, the shortest girl felt most comfortable at the highest board height. These results are indicative of the difficulty in experimenting with the human element, which is unpredictable from day to day and task to task. Electromyographic (EMG) techniques would probably answer some of Knowles' questions on establishing criteria.

Although such work, as accomplished by Knowles, resulted in improved, adjustable ironing boards, other work areas in the home apparently did not benefit. Accordingly, an experiment was designed to determine if an adjustable counter has any effect on easing the homemaker's work load. More specifically, the objective was to determine the effect of counter height on a woman's cardiovascular system while she was working at a representative kitchen task. A mixing task was chosen as most likely to show a difference in the body's response to working at different surface heights. A dishwashing or other such sink center task would have been ideal, but the necessary equipment was not available. By inductive reasoning, the results of any particular experiment, or group of experiments, can reveal pertinent information about a given situation or problem area. Therefore, the mixing task can yield useful data concerning counter height in general, as did the ironing height experiment.

Typical practical examples of a mixing task include mixing a cake batter or stirring a pudding or gravy on the range top. Granted that most mixing tasks can be accomplished with an electric mixer, but even that may require considerable energy and awkward positions of the body to manipulate the bowl and may be done more easily on a lower surface. The hand-held mixer would be the type most likely to be found in an apartment kitchen and is difficult for a short woman to use on a 36 inch counter no matter what the consistency of the batter. Some recipes even call for a batter too thick to be mixed with a hand-held mixer. Applications of this type of experiment are more widespread than the confines of a kitchen. Obviously, any type of industrial task using counters can be subjected to the same analysis, i.e., the counter should be adjusted to the anthropometry of the person using it as well as to the specific task.

The test apparatus for the mixing experiment consisted of a table mounted on a barber chair base to allow adjustment of the surface to various heights. Six inch cinder blocks were placed under the base yielding a range of approximately 26-40 inches for the counter height. Chest electrodes and a Narco physiograph were used to monitor and record each subject's heart rate continuously during each trial of the experiment. Heart rate was selected as the physiological variable most likely to yield consistent results. Knowles (1946) stated that heart rate was the best parameter for revealing significant differences between ironing board heights. More recently, other experimenters have used heart rate to compare shelf heights and ascertain daily energy expenditure of homemakers. Oxygen consumption, calorimetry (the determination of energy expenditure during an activity), and electromygraphy have been used successfully by Ward (1971), Bratton (1959), Richardson and McCracken (1960) and others. The first two techniques, though, are not as consistent as heart rate and more difficult to measure. EMG appears to have real application in the measurement of even slight changes in muscular activity (due to postural changes) caused by different work situations. In the case of work surface height experiments, the critical areas to be monitored would be the lower back, upper leg, and, particularly in a mixing task, the shoulder and forearm. Unfortunately, the only EMG equipment available when this experiment was conducted was particularly suited for static tasks (primarily seated postures) and yielded useless data during test runs for the dynamic task. Therefore, a simple experiment was designed to use available equipment which would yield reasonable data to support or contradict the contention that the standard 36 inch counter height in apartment kitchens (or any kitchen for that matter) is inadequate.

Eight subjects were selected solely on the basis of stature and willingness to participate. Three subjects were shorter than 62 inches, three were of average height (62-66 inches) and two were taller than 67 inches. All but one of the subjects were 20-25 years old, two were full-time secretaries, five were students (one student was also a part-time secretary), and one was a full-time homemaker (former secretary). Three of the women were married. Although the subjects' frames varied from large to small bone structures, all were more nearly average weight (proportionately to height) than heavy set or thin.

Each subject's stature and elbow height were measured and recorded (Table 4). The elbow height was measured with the upper arm vertical and against the body and the forearm parallel to the floor; all the subjects were righthanded. The women wore clothing, including footwear, similar to that they normally wear while working in the kitchen. All but one subject, who preferred bare feet, wore low heeled shoes. From Table 4, the average stature was 65 inches and the average elbow height 40.5 inches. These compare with a USAF study (Clauser, 1972) which concluded that the mean

TABLE 4

ANTHROPOMETRIC AND TEST DATA

Subject	Stature (inches)	Elbow Height (inches)	Adjusted Counter Height (inches)
A	61.5	38.1	30
B	59.9	36.1	30
C	61.3	38.5	30
D	66.8	41.3	32
E	65.0	40.4	32
F	65.8	39.9	32
G	70.3	44.9	33
H	70.0	45.3	34
Ave	65.0	40.5	32

Note: The standard counter height is 36 inches.

stature of Air Force women is 63.8 inches and Barkla's study (Ward, November 1970) stating that the mean stature of the British female population is 63.25 inches. Ward also reported a mean elbow height of 39.3 inches. Since the USAF and British women were barefoot and the women in the mixing experiment wore shoes (one exception) with a half to one inch heels, the various means are reasonably close, indicating that the test subjects were probably a representative sample from a stature standpoint.

The above comparison is more for informational purposes than anything else; actually, it is not appropriate statistically to compare samples from different populations (USAF women, British women, American college students, etc.). No attempt was made to test a sample of the American female population. This study is more concerned with the exceptions to the average rather than confirming or contradicting an existing average.

Murrell (1968) has made some interesting comments on standards and design based on "taken for granted" handbooks such as Woodson and Conover's (1970) or McCormick's (1970) recommendations. His specific points are based on his belief that the standards are based on biased populations such as USAF women or college women. He says inappropriate methods may have been used; the experiment performed may be wrong for the desired outcome. Terms used without exact definition can be misconstrued or interpreted differently by different readers. Age is often erroneously omitted as a factor in experiments. Averages may lead to wrong conclusions: individual differences can be important. He concludes that real-life validation is needed as laboratory results are often biased by motivation of subjects. Practice affects the outcome; therefore, the experimenter must insure the subjects know what they are doing. Of all Murrell's comments, the key for the mixing experiment is that individual differences are important.

Each subject completed two trials in the same day: one at a counter height of 36 inches and the other at a counter height adjusted to the subject's stature (Table 4). The criteria (Table 5) reported by Steidl and Bratton (1968)

TABLE 5

PREFERRED WORK SURFACE HEIGHT (INCHES)
AS A FUNCTION OF ELBOW HEIGHT

Elbow Height	Beating Task	Dishwashing Task	Cutting Task
36	30	31	34.5
37	31	31.5	35
38	31	32	35.5
39	31	32.5	35.5
40	31.5	33	36
41	32	33	36.5
42	32.5	33.5	37
43	32.5	34	37

SOURCE: Steidl and Bratton, 1968.

were applied to the subject's anthropometric measurements and the counter height set accordingly. Then, the subject was asked if she would like the counter lower or higher for the particular task. All indicated that the adjusted counter was at a comfortable height. As expected, the three shorter women were particularly pleased with the adjustment and in fact, very surprised at the difference.

Half the women used the 36 inch counter first and half used the adjusted counter first in an effort to remove learning bias from the experiment. It was arbitrarily decided which subject used which counter first. The two trials for each subject were separated by at least a twenty minute resting period which appeared long enough for the physiological functions to recover from the first trial.

Each subject was asked to blend a bowl of ingredients (two eggs, one cup of flour, and one cup of water), which were slightly pre-mixed to help insure a uniform mixing throughout the trial. The subjects were instructed to stir the ingredients with the technique they would use in their own kitchens but make an effort to maintain a constant speed for the five minute test period. A metronome (about 115 beats per minute) was used to assist the subject in pacing herself and to insure equitable mixing speeds for each trial. The only apparent variable between trials for a subject was the working surface height.

With the subject standing, heart rate was recorded for five minutes prior to each trial, during the five minute trial, and for five minutes immediately following the trial. This particular experiment was expected to show significance for only the shortest women, because for the taller subjects, the "customized" counter was not much lower than the standard. Another experiment such as dishwashing might be expected to show more significant results for taller women, who have to bend over the standard height sink. In fact, for a dishwashing experiment, it would be appropriate to use some male subjects, who generally are taller than females and are often called upon to work at the sink, especially in these times of women's liberation and more equitable distribution of household chores.

The experimental results were as expected. The three shortest subjects (A,B,C) had a greater difference in heart rate between the two trials than the taller subjects. The average heart rate for all subjects increased ten beats per minute over the average resting level for the trial at the 36 inch counter and six beats per minute for the trial at the adjusted counter height. But the average heart rate for the subjects A, B, and C increased fourteen and five beats per minute, respectively. Note that in most cases the heart rate increased rapidly during the first minute or two of the work cycle and then remained relatively stable until the trial was completed. Recovery was also rapid in the first couple of minutes as to be expected.

Analysis of the data was based on the increases in heart rate over resting levels (the five minute pre-trial period) as a result of the work at the different counters. Table 6 lists the heart rate increases for each subject and trial. When all the data were subjected to an analysis of variance, the difference in means between the two trials was significant at the 5% level (Table 7). When the analysis was repeated using the data for the three shortest subjects only, significance was reached at the 2.5% level (Table 8). There was no significant difference between heart rate rest levels for all subjects or subjects A, B, and C alone. The same was true for difference in heart rate work levels. This gives further credence to using

TABLE 6

INCREASE IN TOTAL NUMBER OF HEARTBEATS DURING THE FIVE MINUTE WORK PERIOD OVER THE FIVE MINUTE REST PERIOD IMMEDIATELY PRECEDING WORK

Subject	Standard Counter	Adjusted Counter	Total
A	77	24	101
B	89	44	133
C	39	4	43
D	52	45	97
E	26	44	70
F	13	3	16
G	50	28	78
H	36	48	84
ΣX	382	240	622
ΣX^2	22,713	9,586	57,444

TABLE 7

ANALYSIS OF VARIANCE FOR THE DATA IN TABLE 6

Source of Variation	Sum of Squares	Degrees of Freedom	Estimate of Variance	F-Ratio
Between individuals	4,542	7	649	
Between experimental conditions	1,260	1	1,260	3.81
Residual	2,317	7	331	
Total	8,119	15		

Significant at p = 0.05.

TABLE 8

ANALYSIS OF VARIANCE FOR SUBJECTS' A, B, AND C DATA IN TABLE 6

Source of Variation	Sum of Squares	Degrees of Freedom	Estimate of Variance	F-Ratio
Between individuals	2,081	2	1,040	
Between experimental conditions	2,948	1	2,948	74.88
Residual	79	2	39.5	
Total	5,108	5		

Significant at p = 0.025.

the increase in heart rate (work over rest level) as an indicator of differences between work situations. The results, although not conclusive, indicate that the counter height does have an effect on the amount of energy expended. The heart rate relates to energy expenditure in that increased heart rate while working is directly associated with increased muscular activity, which is commonly associated with burning calories.

Visual observations made on the subjects and the subjects' comments are also appropriate to further support the test results. Subjects A, B, and C in particular noted that fatigue was greater while working at the standard counter. The reason for the fatigue was obvious; the shorter woman was required to mix the ingredients with her elbow well away from her torso (Figure 3). In two cases, the upper arm was nearly parallel to the floor. This awkward position is inefficient as the shoulder is abducted and more work is required to complete the task. The static loading on the arm is increased simply to keep the arm in the raised position. With increased static loading, fatigue is likely to appear more rapidly. When the adjusted counter was used, a marked difference was evident. The elbows were brought in close to the body with the upper arm nearly vertical (Figure 3). Much less energy is required if the upper arm operates while nearly parallel to the body center line.

On the other hand, the five taller subjects could

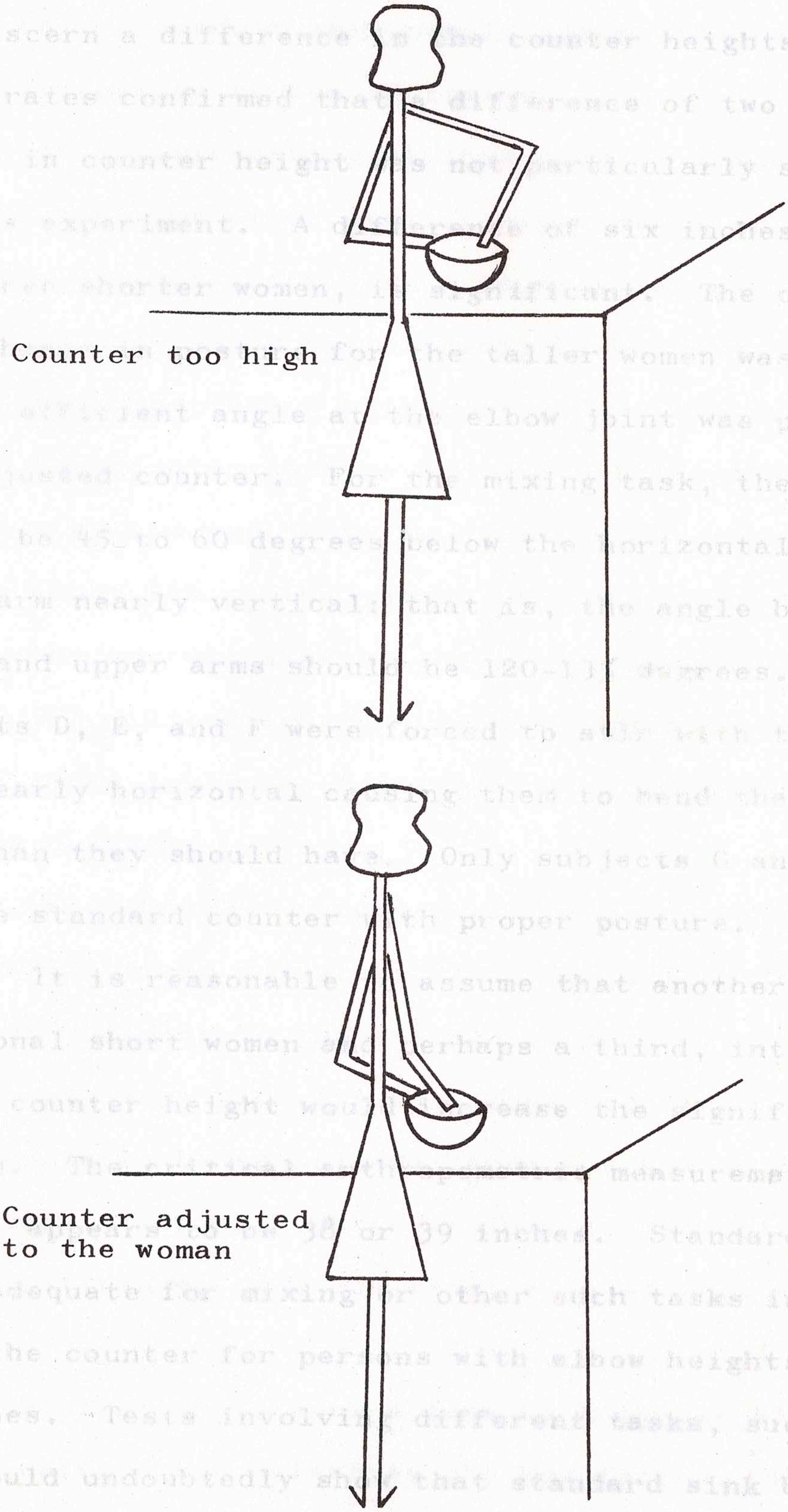


Figure 3. The effect upon posture of different counter heights.

not discern a difference in the counter heights. Their heart rates confirmed that a difference of two to four inches in counter height was not particularly significant in this experiment. A difference of six inches, as with the three shorter women, is significant. The only noticeable change in posture for the taller women was perhaps that a more efficient angle at the elbow joint was possible with the adjusted counter. For the mixing task, the lower arm should be 45 to 60 degrees below the horizontal with the upper arm nearly vertical; that is, the angle between the lower and upper arms should be 120-135 degrees. Even subjects D, E, and F were forced to stir with their lower arms nearly horizontal causing them to bend their wrists more than they should have. Only subjects G and H could use the standard counter with proper posture.

It is reasonable to assume that another test using additional short women and perhaps a third, intermediate or lower, counter height would increase the significance of the results. The critical anthropometric measurement, elbow height, appears to be 38 or 39 inches. Standard counters are inadequate for mixing or other such tasks involving work above the counter for persons with elbow heights less than 39 inches. Tests involving different tasks, such as dishwashing, would undoubtedly show that standard sink bowl heights (five to six inches below counter height) are even more inadequate for persons taller than 70 inches, which includes nearly half the adult male population of the United States and an increasing number of females.

It is interesting at this time to compare the mixing task results with other similar experiments or studies on women's preferences for work area heights. Using electromyographic and psychophysiological techniques, Saville (1969) has found that a height of 900 millimeters (35.4 inches) for counter surface and 975 millimeters (38.3 inches) for the sink rim and draining boards gives reasonable comfort to about 75% of the women. For the shortest 22%, though, the current sink height of 900 millimeters with a bowl of 175 millimeters (6.9 inches) depth is more suitable. These figures imply the desirability of adjustable counter and sink heights.

Ward's (1971) recommendations are strongly in favor of flexibility and adjustability. She states the compromise answer of building to the average is totally unsatisfactory and the easy way out. She has found a counter top height of 33-39 inches to be an optimum range for 95% of the British female population with three or four adjustments desirable within that range. For the sink, a 36-42 inch range is optimum.

Steidl (1955) took a look at separate electric oven heights using elbow height as the key factor. With 50 women in the survey with varied elbow heights from 35 to 46.5 inches, she determined the opened oven door should be at a level of one to seven inches below the elbow height (three inches being most popular). This wide range demonstrates the importance of individual adjustment for appliances as well as work surfaces.

All studies have shown that women prefer to have their elbows above the work surface regardless of the task. This is not surprising and confirms the mixing task results that a 36 inch counter is certainly too high for women under five feet tall and difficult to use for women as tall as 5'3". The next chapter looks at the economics of adjustable counters and in particular, the most cost-effective method of providing the flexibility espoused by Ward (1971).

CHAPTER V

ECONOMIC ASPECTS OF ADJUSTABLE COUNTERS

Any time ergonomic studies show a need for a change in design of a piece of equipment, the benefits to the worker and management must be weighed against the incremental cost of the new design. In other words, is the cost increase justified by an increase in production, improved employee morale, less turnover of employees, fewer hours lost due to injury, or some other factor? Many of these same criteria can be applied to an economic analysis of the value of mass-producing cabinets with adjustable counters.

Before costs can even be considered, a feasible design must be found. There are numerous ways to build a cabinet with an adjustable counter. Unfortunately, most of them cause a loss of storage space. For instance, a relatively expensive method is to use a motor driven jack mechanism built into the base of the cabinet. Ward (1972) describes an adjustable kitchen using such a system designed by Barry Wingate of Leicester Polytechnic, England. Wingate has even included flexible plumbing connections so the sink can be raised and lowered. For the purpose of this thesis, only counter working surfaces will be adjustable. The sink is really another problem to be explored in detail.

Another costly method is to use a pneumatic device, such as that used with barber or dentist chairs. At first glance, this does not seem practical in that storage space would be too limited once the mechanism was built into the cabinet, but with careful design practices, this solution would probably have some merit.

The above methods have the advantage of a possible continuous range of counter heights but the disadvantage of high cost. Although accurate cost data are not presented, if electrical or pneumatic devices are introduced, the cost of a wood cabinet will be raised considerably. The above devices are probably appropriate, though, when considering overall kitchen design, i.e., futuristic modular kitchens. For this thesis, the investigation will be limited to a design improvement which could conceivably be sold to retrofit existing cabinets. All that is needed is a simple discrete method for allowing the worker to size the kitchen to his or her stature. The major constraint for selling this idea is uncomplicated: do not affect the apartment rent.

Discrete adjustment implies pre-selected increments for raising or lowering the counters. Based on the previous chapter, a range of 30-39 inches should be sufficient, although up to 42 inches may be desirable. In any case, increments of three inches are selected for pricing purposes. It would be a simple matter to use one or five inch increments if desired, but less than two inches would probably be an excessive number while more than four inches would tend to negate the advantages of the adjustment.

A standard base cabinet is just under 30 inches high, which gives an ideal starting point. Currently, a drawer and counter top added to the cabinet yield the 36 inch standard. To make the counter adjustable, the drawer must be eliminated, at least for the lower counter levels. This causes a problem but can be overcome by including a cabinet of drawers in each kitchen, which is a good idea in any case and can be the subject of another study. Another method is to use drawers for all cabinets rather than doors and shelves.

A rough sketch of the proposed design is shown in Figure 4.* Basically, the design calls for two additional .5 by 23 by 12 inch panels attached to each side (inside) of the standard cabinet. The counter top is fixed to the new panels. The counter and panels are raised and lowered using pin or dowel construction. Holes drilled into the basic cabinet at three inch increments allow the counter to be raised to a specified height and the pins slipped in place to constrain the counter in the selected position. The opening in front caused by raising the counter is filled by another panel which slips in place and clips to the inside panel structure. Two front panels are needed for a 30-39

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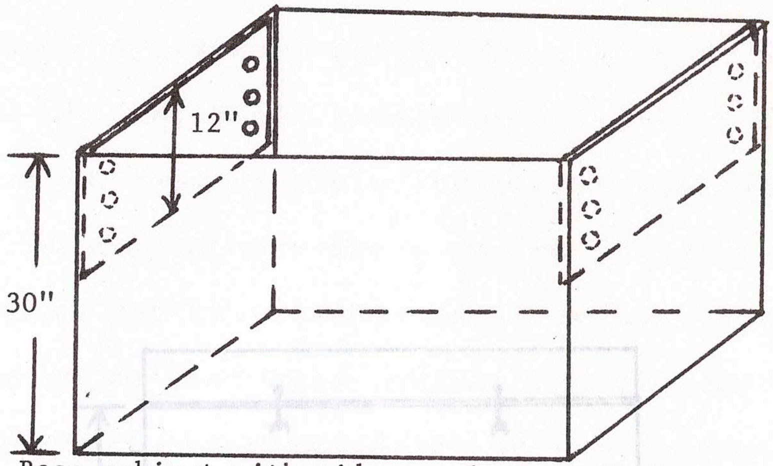
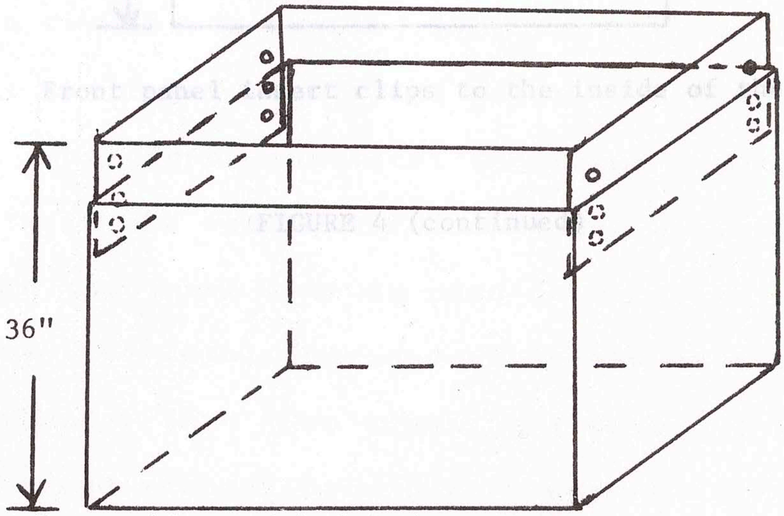
*Mr. Olfers, a cabinet designer for George C. Vaughan and Sons of San Antonio, evaluated and refined the design and provided the cost figures presented later in this chapter.

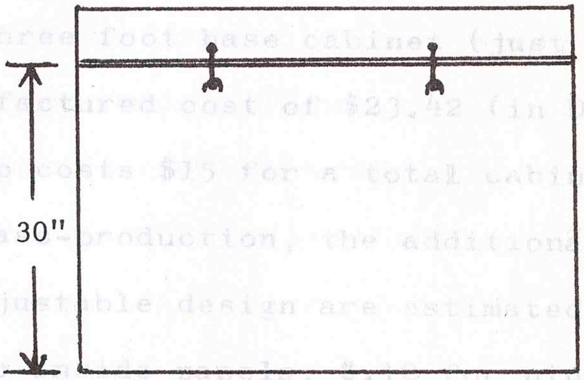


a. Base cabinet with side panels installed



b. Base cabinet with 6 inch extension in place

FIGURE 4--Proposed Design for Adjustable Counters
(Counter Top Removed)



c. Front panel insert clips to the inside of the cabinet

FIGURE 4 (continued)

inch range. A three inch panel is used for a 33 inch counter height, a six inch panel for a 36 inch counter, and both the three and six inch panels for the full 39 inch counter. When not in use, these panels are attached to the inside of the cabinet to complete the self-contained unit.

Of course, the above design is rough and may not be the best but it is sufficient for cost estimating. A standard three foot base cabinet (just under 30 inches high) had a manufactured cost of $23.42 (in December, 1974); the counter top costs $15 for a total cabinet cost of $38.42. Based on mass-production, the additional costs per counter for the adjustable design are estimated as follows: $.92 for the two inside panels, $.12 for pins or dowels, $.44 for the two front panels and clips, and $.48 additional labor. Therefore, the total additional cost is $1.96 or an increase in the manufactured cost per cabinet of 5%. Assuming each apartment kitchen used no more than three such cabinets, the total increase wholesale cost per apartment is just under $6. Even assuming a doubling in cost due to taxes and manufacturer/distributor/builder profits and possible underestimation of costs, an increase of $12 per apartment is hardly significant. For instance, if the cost of building an 800 square foot apartment is $20,000 ($25 per square foot), the adjustable kitchen counters increase the cost by a small .06%. Increasing a $200 per month rent of which at least $80 covers taxes, utilities and extras such as swimming pools, game rooms, etc., by .06% results in about $.07. This amount can easily be absorbed or taken into account when inflation causes rental increases.

The conclusion is that discrete adjustable counter design, such as presented in this chapter, is indeed cost-effective, regardless of the value of advertising adjustable counters which conceivably could be the difference between empty apartments and no vacancies. Better overall kitchen design, which encompasses a great deal more than simply adjusting counter heights, can mean happier tenants, less turnover, and increased profits for apartment owners.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

This investigation of the apartment kitchen work place began with the identification of two problems, namely "slick" or "streamlined" cabinet construction (one standard counter height) and limited counter space. Although in the past twenty years there have been great improvements in kitchen appliances, such as dishwashers, garbage disposals and self-cleaning ranges, the counters have remained at a constant 36 inch height. The mixing experiment described in Chapter IV lends credence to the contention that adjustable counters can indeed decrease fatigue and make kitchen work less tedious. Other documented experimental work in this area was presented as further justification. The economic analysis showed that a "quick fix" is cost-effective even if a sophisticated electrically-operated adjustable cabinet is not.

Consumer education appears to be the key in convincing architects and cabinet makers of the desirability of adjustable counters. Standard counters may possibly be associated with medical problems and at least aggravate back aches and tendinitis or arthritis in wrists, elbows or shoulder joints in particular. People suffer these pains without realizing an adjusted counter may offer relief. Therefore, this is another case where human engineers face a seemingly insurmountable problem of educating the populace, who have been conditioned to using poorly designed equipment for so long that they cannot recognize the causes of cronic pain and fatigue.

The second problem, limited counter space, was confirmed by an apartment survey in which all apartments began to look identical. There has been little innovative design in apartment kitchen work place layout. Architects have done wonders with houses where space is relatively unlimited, but apartment kitchens seem to suffer the rectangular niche syndrome. The counters are unceremoniously interrupted by the major appliances rather than complimenting them to provide an integrated, efficient work area. The problem is a poor use of available space, because generally, there is enough room to provide a comfortable working area if properly engineered for meal preparation and not solely for aesthetics. For apartment dwellers at least, the outlook does not appear much brighter in the future, as new apartments are perpetuating the standard kitchen designs. Some radical changes are needed, and economics and education are the answers to initiating those changes.

The total systems concept can be readily applied to modular kitchen design. The cabinets available now are a step in the right direction but many easy-to-implement ergonomics principles, such as those discussed in this paper, have not been considered as yet. More studies are needed to integrate adjustable sinks, cooktops, and storage space with the concept of adjustable counters. The sink is a key area of concern as mentioned previously. Heiner and McCullough (1948) and Steidl (1961), among others, have done extensive research on storage and the need for flexibility and adjustability. In fact, Heiner and McCullough coined an appropriate and descriptive motto for kitchen designers: build the cabinets to fit the woman; build the shelves to fit the supplies; and build the kitchen to fit the family.

Other areas to be considered for further study include the use of electromyographic techniques in determining the work load on the kitchen worker. This could be done in conjunction with taller people working at the sink as well as shorter people working at standard counter heights.

The kitchen, as the most critical work area in an apartment or house, deserves to be thoroughly planned and integrated into the overall design scheme to the best advantage of the residents. The technology is available to achieve great advances in improving the kitchen work place. The human engineer's problem is convincing the populace and building industry of the benefits to be realized from applying ergonomic principles while holding the costs of design change to a level acceptable to the consumer.

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This thesis by Robert H. Van Dyke has been used by the following persons, whose signatures attest their acceptance of the above restrictions.

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