# AN INVESTIGATION OF SAFE HANDLE DESIGN

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## ABSTRACT

This study examined possible handle configurations for meat-packing knives. The first phase examined nine handle shapes and four sizes (36 handles total) for the maximum forces that can be exerted on them. This involved six separate maximum force tests. Next, 11 handles were selected, based upon their performance in the six maximum force tests, to be evaluated in two fatigue tests - one using a constant static load, and the other using a constant static load with intermittent impulses. Time to fatigue was measured. Finally, one handle was used with all combinations of tang guards of four heights and three radii of transition from the handle to the guard, to test the maximum force which subjects could exert in the thrust push direction. All tests were conducted under the condition of a slippery film in order to accentuate or magnify any inherent differences in the handles and guards.

Handle shapes, sizes, and shape-size combinations were identi-fied which were associated with the high forces on each of the six maximum force tests. The fatigue tests failed to indicate any differences between the 11 handles tested in this manner. The guard test indicated, for the range of radii tested, the radius of transi-tion had no effect on maximum forces. However, guard height did affect the maximum force capability and a minimum effective guard height for males and one for females was determined. When compared with these minimum heights, most handles on knives currently avail-able for meatpacking were found to be inadequate.

# ACKNOWLEDGEMENT

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# I. INTRODUCTION

## I.A. Need

State and national meat packers have expressed an interest in reducing knife related accidents. Each year these accidents cost them, and ultimately the consumer, millions of dollars. This safety related research will be a step in reducing the number and cost of these accidents.

Present day meat packing has evolved from a small butchering operation into a huge industry using modern work methods. In this evolution many things have changed, but the basic tool, the knife, remains relatively unchanged. The knife is involved in many "lost time" accidents and permanent disability cases nationally. A real problem in knife design is the configuration and size of the handle.

As the workers in the meat packing industry perform their assigned tasks of cutting carcasses over an eight-hour day, fatigue sets in. This is especially true of the muscles involved in maintaining grasp as these muscles are statically loaded. Static loading of muscles inhibits blood flow necessary to bring replacement energy supplies and remove waste products critical to muscle metabolism. This causes accelerated fatigue in the muscles involved. To accentuate and accelerate this problem the knife handle becomes slippery due to body fluids of the slaughtered animals. A tighter grip is required, which causes more static loading of the muscles.

Occasionally the worker, in attempting to jab the knife into the meat, hits a bone, stopping the penetration of the knife. If the hand slips, it slides over the blade, with the possibility of severe and often permanent damage.

Present knife handle designs do little to prevent this sliding over the blade. They provide an indention or small tang to stop the first finger from going forward. This is inadequate when the knife is slippery

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and/or fatigue is present. Many handles are wood, which will become slippery when wet with animal body fluids. Those that are plastic are sometimes made with a rough or textured surface to inhibit sliding. This too is defeated by the body fluid slipperiness.

One attempt at a solution to this problem has been to have the worker wear a chain mail or nylon mesh glove to protect his hand. This has several drawbacks. It increases fatigue, decreases grip capability, is clumsy to wear, is hot, and becomes dirty. Also, as the glove becomes worn and abraded, it is more comfortable to wear but it affords less than adequate protection.

To prevent hands from slipping over knife blades in the meat packing industry, knife design needs to be investigated from two points of view. First, an investigation to determine the optimum handle size and configuration to minimize fatigue and maximize grip capability needs to be conducted. Second, development of a guarding system such that it is very difficult or impossible to slip the hand from the handle onto the blade is needed. This guard has to be compatible with the task such that it does not inhibit the work or interfere with productivity.

This research tested a variety of handle design configurations (including some similar to those now being used in the industry) to determine which are best suited for knives. These handles were tested for grip capacities, resistance to slippage under conditions of thrust and rotation or twist. Fatigue characteristics of the better designs were also evaluated relative to thrust operations. Also tested were a variety of guard designs. These designs were evaluated on their ability to prevent hand slippage off of the handle and onto the blade.

The output of this research is a group of handle and guard designs which

are appropriate for knife handles used in the meat packing industry. Guidelines on which handle configurations are best and what types and sizes of guards are adequate for prevention of slippage over the cutting edge have been developed. A viable methodology for evaluating handle configuration and guard designs was developed which can be extended to all types of tools.

## I.B.  Present Knife Handles

Knives used in meatpacking primarily come from two manufacturers - Chicago Cutlery and Dexter Russell. Chicago Cutlery manufactures numerous kinds of wood-handled knives, all of which use the same basic shape and size of handle, with minor differences in the dimensions. The basic shape and dimensions for three of the Chicago Cutlery handles are in Table I-1. Dexter Russell has two handle designs (wood and plastic) and all of each design are identical to each other. The dimensions of these handles are also given in Table I-1.

The Chicago Cutlery and the Dexter Russell wood-handled knives are the most common in the author's experience in meat packing. These handles range in circumference or perimeter length from 7.37 to 9.40 cm. Ayoub and Lo Presti, 1975, found for cylindrical handles the ideal is somewhere between 11.94 and 16 cm for minimizing fatigue. Some difference between the ideal cylindrical handle size and what might be the ideal meat packing handle size is expected due to the nature of meat packing tasks. However, this difference appears to be excessive. In addition, the length of the gripping surface of these knife handles (f) is about what would be expected to fit the breadth of the hand for only 25 percent of the male population (NASA, 1978).

The tang, indention or guard which is supposed to keep the hand from

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sliding forward over the cutting edge appears to be totally inadequate for the Chicago Cutlery handles, possibly marginal for the Dexter Russell wooden handle, and probably adequate for the Dexter Russell plastic handle. This is evidenced by dimension h, which is the difference between dimensions a and g (Table I-1). Also of importance is the radius of curvature (Table I-1) of the transition from the handle to the tang or guard. On all but the Dexter Russell wooden handle this radius is small, which tends to make the guard more effective. On the Dexter Russell wooden handle this radius is much larger (.25 cm). This tends to function as a ramp and facilitates the finger slipping over the tang.

## I.C. Knife Handle-Hand Positions

There are four basic positions in the hand in which a knife can be used in meatpacking. All involve the power grip in one form or another. The four positions are shown in Figure I-1 along with names for each (created for this report). In the experience of the authors the slicing and inverted slicing positions are used for most cuts in meat packing. The stabbing position is also used regularly but the inverted stabbing is used much less frequently. Although there are other positions possible, such as half inverted, they are not stable in the hand as the narrow side of the handle rather than the wide side is in contact with the palm. Throughout this report references will be made to these four standard knife-hand positions.

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TABLE I-1

Dimensions of Knife Handles Currently Used
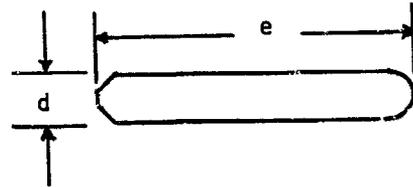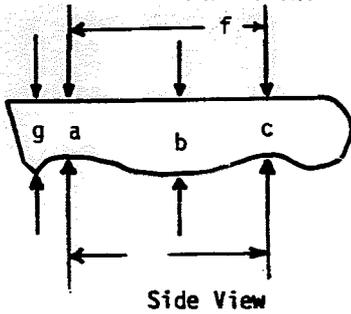


Side View                    Russell Knife        Top View

| Knife | a | b | c | d | e | f | g | h (g-a) | r |
|-------|---|---|---|---|---|---|---|---------|---|
| | | | | | Dimensions (in centimeters) | | | | |
| Russell Plastic Handle | 2.77 | 3.28 | 3.15 | 2.24 | 13.34 | 8.26 | 4.45 | 1.68 | .53 |
| Russell Wood Handle | 2.29 | 3.00 | 2.62 | 1.87 | 13.34 | 8.26 | 3.18 | .89 | .95 |
| Chicago 94-5 | 1.83 | 2.84 | 2.54 | 2.16 | 11.43 | 9.86 | 2.24 | .41 | .56 |
| Chicago 96-6 | 2.01 | 2.90 | 2.62 | 2.16 | 11.43 | 9.86 | 2.24 | .23 | .61 |
| Chicago 72-2 | 2.08 | 2.84 | 3.00 | 2.16 | 11.76 | 10.03 | 2.54 | .46 | .60 |
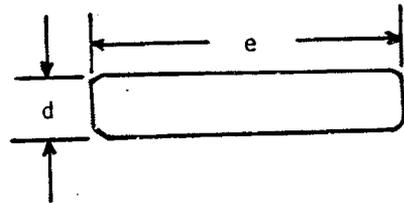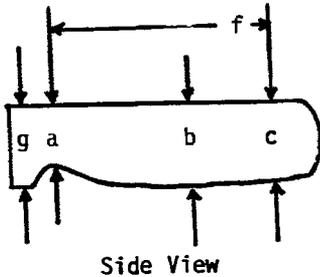


Side View                    Top View

Chicago Knife

Slicing Position



Inverted Slicing Position



Stabbing Position



Inverted Stabbing Position

Figure I-1.   Knife Handle-Hand Positions

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As has been indicated in the introduction, the present knife handle design does not significantly reduce the potential hazard to the worker, and no relief is in sight. Although many textbooks and design books talk about handle design, they never address the problem of size and configuration to minimize fatigue or maximize capability. They neither specifically describe the design nor do they cite research that supports particular handle designs. Considerable work has been done on grip strength. These studies do not address handle size, shape and force capability, or fatigue. There are, however, several that have briefly examined some aspect of handle design.

Pheasant and O'Neill (1975) examined various screwdriver handle designs availab le in Great Britain and compared them with smooth and rough cylinders. They found no difference in torque capability and the handle shapes available. They did find that twist and capability · increased as handle diameter increased from 1 to 3 cm with a leveling ' off tendency from 3 to 5 cm and a drop from 5 to 7 cm. They found 5 cm to be the best diameter for cylindrica⁷ handles. They did not investigate fatigue or long-term performance.

Patkin (1969) found that cylindrical handles needed a flat side to "improve control of possible twisting." Mr. Patkin also used electromyography to control "good and bad" handle designs. Patkin has done considerable other work on handle designs but in the more delicate area of surgical instruments.

Ayoub and Lo Presti (1971) conducted a study to find the optimum size of cylindrical handles by use of electromyography. They found that for cylindrical handles of approximately 2.54 to 6.35 centimeters in diameter, electromyography indicated no difference in effort, with dramatic increases

outside of this range. They did do a fatigue study and found the 6.35 diameter was inferior, dropping the optimal range to 2.54 to 5.08 cm. This compares very closely to the Pheasant and O'Neill results.

In summary, some work has been done to establish the optimum size of cylindrical handles. Little quantitative work has been done on other designs. Also, there is no good methodology established to do this.

The early articles that were found on knife handles and safety (national Provisioner, 1948 and 1949) discussed the same problems meat packers are having today. Massy (1949) discusses methods of guarding and the problems guards present. Loop guards, side shield guards, and tang guards are suggested as solutions to specific task problems. Generally favored were side shield guards and notched (special case of the tang guard). From the appearances these were of minimal height and probably of minimal protection.

Garrett (1971) studied numerous anthropometric measures of the hand and force capabilities of the hand with and without gloves for the U.S. Air Force. In one of his studies he compared the two hundred forces which subjects could exert on four different handles. Because the handles were related to the ejection activation from aircraft and were two-handed in their use, they have no relationship to the present study of knife handles.

Drury (1980) examined handles for materials handling in two experiments. The first found that subjects were willing to hold a load with a cylindrical handle of 2.0 cm diameter (6.28 cm circumference) longer than those of greater or lesser diameter. The second found the optimum between 3.1 to 3.8 cm in diameter (9.74 to 11.94 cm circumference) based upon subjective ratings. Drury's conclusions are that handles should be 11.5 cm long and between 2.5 and 3.8 cm in diameter.

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Bobbert (1960) investigated the parameters of hand grips to be molded into concrete blocks. Shapes and dimensions were developed by examining the contours of the hand in grasping for lifting. These were evaluated for maximum lifting power. The shapes and sizes tested were specifically for lifting and are inappropriate for knife handle designs.

Saran (1973) investigated "T" handles for pronation and supination tasks. Dr. Saran investigated the angle of the "T" and the size of the grip surface. Angles varied from 90° down to 60° and sizes varied from 1.91 cm to 3.175 cm in diameter of cylindrical handles (5.98-9.97 circumference). Subjective ranking found the 60° angle to be optimum and 2.54 cm (7.98 cm circumference) to be the optimum size.

Armstrong et al. (1981) analyzed the problems of trauma disorders of the upper extremity in a poultry processing plant. They found excessive wrist flexion and ulnar deviation while exerting force on jobs using knives. The recommendations included using larger handles on the knives, banana-shaped knife handles, and even pistol-like grips for some operations. Also, straps to prevent the hand from slipping off the handle were recommended.

Riley and Cochran (1980) conducted a study to improve knife handle design. Upon examining the cross sectional perimeter of knives being used by a meat packing company, they determined that the handles were probably too small. Also, it was determined that the length only fit the lower 25th percentile of American models. Numerous handles with increased cross-sectional perimeter and increased length were given to meat packing personnel to use for a day. Workers were questioned extensively after using each design. The result was a consensus among the working meat packers for a particular handle which was both larger in cross-sectional perimeter and in length.

III. **METHOD - GENERAL**

III.A. Overview

The proposed research was conducted in three phases. The first is concerned with evaluating maximum force capability with various handle configurations. The second phase uses handles selected based upon the results of the first phase and tests them for fatigue characteristics. The third phase uses one handle configuration and tests it with a variety of guard designs. In addition to the three phases (which are oriented toward knife handle design), an evaluation of the handles for manual materials handling was conducted. A complete discussion of this is contained in Appendix A.

In the first phase handle designs were evaluated on the following characteristics:

1. Thrust - The maximum amount of pushing force and pulling force that can be exerted (see Figures IV-1 and 2).

2. Push-Pull - The Maximum amount of push or pull force that can be exerted in a horizontal plane when the handle is maintained in a vertical position and fixed at one end (see Figures IV-3 and 4).

3. Torque - The maximum amount of rotational force that can be exerted (both flexion and extension movement of the wrist). (See Figures IV-5 and 6.)

Thrust, push-pull, and torque were evaluated for each handle design tested and the maximum force was recorded as the dependent variable. These tests were conducted under a reduced friction condition. In this situation the individual wore a disposable plastic glove and the handle was coated with a slippery film to simulate meat packing conditions and eliminate texture playing a role in the evaluation (see a discussion of this methodology for phases one and two later in this section of the report).

Fatigue or the rate of fatigue was tested in two ways - both using the glove and the slippery film method. The first type of fatigue test (static fatigue test) had the subject hold the handle, as in the thrust test (Figure IV-1), against a constant, submaximal force until he/she could no longer maintain the force or slippage on the handle occurred. The second type of fatigue test (impulse fatigue test) had the subject maintain a constant force, as in the first type, with the addition of periodic jerks or rapid but short duration increases in the opposing force. This closely simulates the meat packing requirement to jab the knife into the carcass. In both fatigue tests the time until loss of grip was recorded.

Nine different handle shapes were tested in sizes having perimeters varying from 7 to 13 centimeters. Included in this were handle shapes similar to those now available on knives used in meat packing. Specific handle shapes and sizes are discussed in detail later in this section.

Anthropometric measures of hand size and strength on each subject were taken and analyses run to ascertain any relationships between these measures and performance on the various shapes and sizes of handles.

From these first two phases came a hierarchy of shapes and sizes of handles which are superior on one or more of the tests. Those found to be superior on the thrust were considered first for inclusion in the second phase of testing - the fatigue tests. Also from the first phase

came an analysis of what factors contribute to good or poor performance of handle configurations on each individual test.

The third phase tested guard designs for knife handles. The test was a repeat of the thrust test under reduced friction. In this case the subject was allowed to use the guard (which was also slippery) to push against as long as no part of the hand went over the guard.

The test on guards evaluated the subject's ability to prevent the hand from slipping over the blade. Twelve guards were tried. Data analysis was similar to that of the handle shape and size. This time the independent variables were guard parameters.

This research provides a thorough evaluation of the force capabilities and the fatigue characteristics of various handle sizes, shapes, and guards. The tests used provide a methodology that is simple and repeatable for evaluating future designs. With this foundation, other handle problems can be investigated.

III.B. Slippery Film Method

All testing for this report was conducted under slippery film conditions. That is, a slippery film was applied to a handle prior to its being grasped by the subject for a trial. The purpose of this was to eliminate the effect of the surface finish of the handles and to get a more accurate assessment of the inherent characteristics of each handle. It was also felt that the slippery film would accentuate any advantages or disadvantages of a handle and that this would make the tests more sensitive to real differences in the handles. To insure that the coefficient of friction was constant from trial to trial, a disposable plastic glove, which was covered with the slippery liquid, was worn. This also prevented the liquid from being absorbed by the hand and made for an easy clean-up.

Numerous materials were tried as the slippery liquid, with very little

effects on the tests. The only one that was really effective in reducing the friction between the plastic glove and the plastic handle was "STP", the engine oil additive. "STP" appears to be thick or very viscous but it did not break down and it did maintain a slippery film between the plastic glove and the plastic handle.

III.C. Handles

The handles used in this experimentation were machined from solid plexiglass to the shapes and sizes desired. All handles were then sanded with progressively finer grit sandpaper until all had a fine, uniform satin finish.

Nine handle cross-sectional shapes were tested. These shapes, along with the letter used to designate them throughout the experimentation and this report, are represented in Table III-C-1. These shapes were selected because, in the experimentors' judgement, they represented those which are most likely to be successful, accepted by meat packers, and/or able to be mass produced. Each handle had straight, parallel sides and the same cross-sectional shape and size throughout its length.

The circular handles were included not because it was thought that a meat packing knife should ever be cylindrical, but because most of the research done on handles in the past has used cylindrical ones. Therefore, in order to compare this research with past work, it was advisable to include cylindrical handles. Circular handles with one or two flat sides were included as they presented viable alternatives to the rectangular ones.

Equilateral triangular handles were included as an alternative to rectangular and circular ones. Although triangular handles have a feel that is appealing to some people, they do have some disadvantages. The angles are by the nature of the triangle more acute than rectangular or

| Description of the Cross Section | Ratio of Width to Height | Symbol | Cross Section |
|---|---|---|---|
| Circular | 1:1.00 | (C) | |
| Circular with flat side | 1:1.25 | (D) | |
| Circular with two flat sides | 1:1.25 | (O) | |
| Triangular | 1.13 | (T) | |
| Square | 1:1.00 | (S) | |
| Rectangular | 1:1.25 | (W) | |
| Rectangular | 1:1.50 | (X) | |
| Rectangular | 1:1.75 | (X) | |
| Rectangular | 1:2.00 | (Z) | |

Table III-C-1.  Handle Shapes Tested

circles with flat sides. This may cause more of a pressure point on the hand. Also, there is a question of orientation. Most people feel that a flat or side should be against the palm. However, some feel that one of the apexes (rounded) fits nicely into the palm. Finally, in meat packing jobs where the knife needs to be used in several of the hand positions discussed in the introduction of this report, the triangular handle may be inappropriate.

The last type of handles included in the study were the rectangles with rounded corners. There were five types of rectangles used based on the ratio of the width to the height. Those ratios were 1:1.00, 1:1.25, 1:1.50, 1:1.75, and 1:2.00. These rectangular handles vary from those with equal width and height (square) to those with quite smaller width than height and would encompass the ratios of all meat packing knives in wide use today.

For exact specifications of the handle dimensions, see Appendix C.

III.D. Subjects

Subjects for this research were obtained from a wide variety of sources. All samples were divided evenly between males and females. A concentrated effort was made to recruit subjects with meat cutting experience, which resulted in approximately half of the subjects being currently employed as meat cutters or having had past employment as such. The remainder of the subjects were mostly machinists, technicians, laborers, along with a few teachers, students, housewives, and secretaries. When the latter were used, only those with a recent history of manual labor of some sort were used.

III.E. Apparatus

The pieces of apparatus utilized in this study can be divided into two categories - force measurement and force maintenance. The force measurement apparatus was required to quickly and easily measure force. Two types

were used, one for tension force and the other for rotational force or torque. The force maintenance equipment was required to maintain a constant force in opposition to a subject holding a handle.

1. Tension Force Measurement

For four of the tasks of phase 1 and for the task of phase 3, it was necessary to measure the maximum push or pull on each handle. In these tests the subject was seated, grasped a handle and pushed or pulled against a cable attached to the lever, shown in Figure III-E-1. Another cable attached to the other end of the lever was threaded around a pulley and through a cable tensiometer to a stud. As can be seen from Figure III-E-1, this arrangement kept the cable parallel and in line with the tensiometer. When the subject pulled on the handle attached to the cable, the resultant force activated the tensiometer which has a peak indicator. There was minimal movement in the apparatus and cable upon application of force so that this would be considered a static force measurement. This apparatus was mounted on a piece of hard wood and fastened to a vertical shaft which was mounted on the wall (Figure III-E-2). The entire apparatus pivoted around this shaft and was adjustable up and down on the shaft. This allowed for alignment so that the subject was always pulling at a right angle to the lever, thereby keeping the mechanical advantage of the lever consistent throughout the experimentation.

The cable tensiometer was a model T5 manufactured by Pacific Scientific Co. The entire lever, pulley, and tensiometer apparatus was calibrated at the beginning of the study and checked periodically during the experimentation.

2. Torque Measurement

For two of the tasks of phase 1 a measurement of torque was necessary. For this a Snap-on model,TQSS2FU with a scale from 0 to 384 oz and accurate
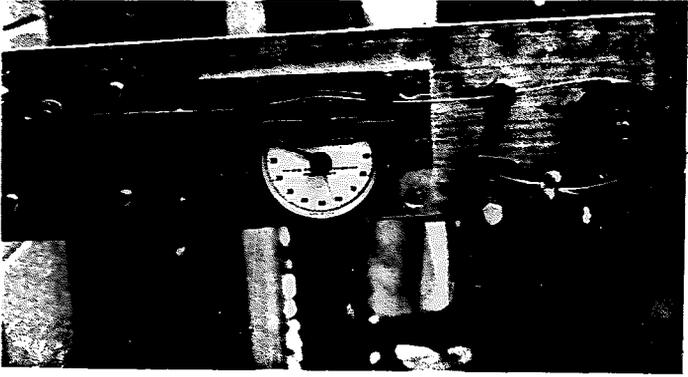
Figure III-E-1. Mounted Cable Tensiometer,
Pully and Lever



Figure III-E-2. Cable Tensiometer Assembly
with Rotating Height Adjustable
Wall Mount

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within 1% at full scale, torque wrench (Figure III-E-3 was mounted on a table which was adjustable in height. This was connected via gears and a chain drive to a 1-inch square socket (Figure III-E-4). To test a handle for torque, the subject inserted the 1-inch square end, which all handles had, into the socket. The experimenter adjusted the table until the handle was in position for the subject's hand. This required that the subject stand erect with his/her arm at his/her side. Once these adjustments were made, the maximum torque could then be tested for that subject and that handle.

The entire torque measuring apparatus was calibrated before experimentation began and checked periodically during testing.

3. Force Maintenance

For both fatigue tests of phase 2 it was necessary to oppose the push of the subject on a handle with a constant force. This was done by attaching a cable to one end of the handle, running it over a pulley, and down to a weight (Figure III-E-5). The pulley (as was the pulley in the force measurement equipment described earlier) was mounted via ball bearings on a shaft and so contributed minimal friction to the system.
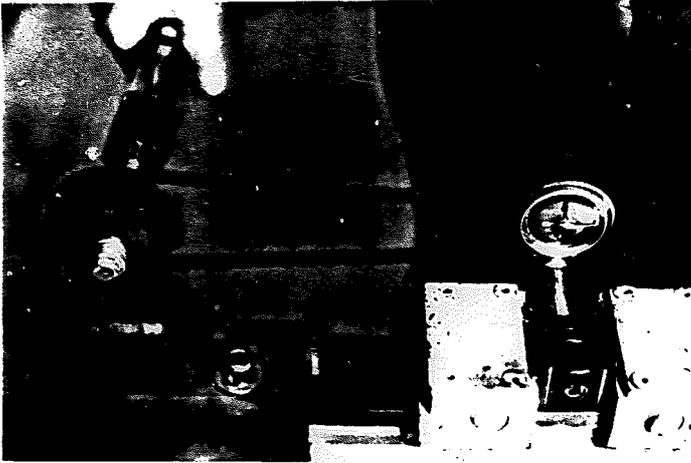
Figure III-E-3.  Torque Wrench and
Chain Drive Assembly
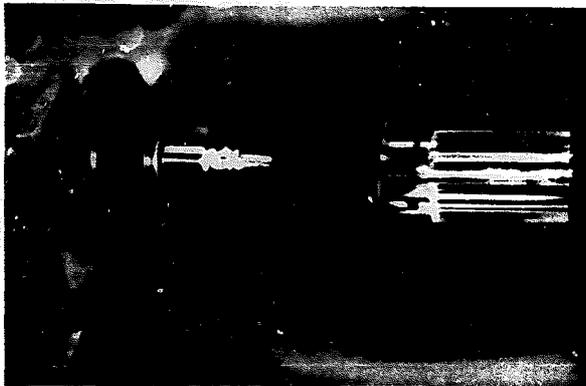


Figure III-E-4.  One-Inch Square Socket with
Square End of Handle
Partially Inserted

Figure III-E-5.  Cable, Pulley and Weight Used
              in Maintaining Constant Force
              for the Fatigue Tests

## IV.   METHOD, RESULTS AND CONCLUSIONS - PHASE 1

The method, results and conclusions for phase 1 are presented separately for the six tests conducted. Prior to covering these, it is worthwhile to cover some topics common to all six tests.

All tests in this phase were maximum force tests and three replicates were gathered. In the push and pull tests the subject was seated in a chair holding a handle (with disposable plastic glove and slippery film) which was attached by one end to a cable which ran through a cable tensiometer (see Section III-E-Apparatus). The subject was asked to push or pull on the handle with as much force as possible. For the torque tests the subject stood with the handle inserted into a socket which was attached to a torque measuring device (see Section III-E-Apparatus). The subject was asked to exert a maximum rotational force (flexion or extension) on the handle.

In addition to the force measurements, eleven anthropometric measurements of the subjects' hands and arms were taken and recorded for phase one and phase two of this project. These measurements included hand thickness, hand breadth, hand circumference, hand length, fist circumference, palm length and forearm circumference, as described in NASA Anthropometric Source Book, Vol. II (NASA, 1978). The four other measurements were grip diameter, finger circumference, forefinger length and thumb crotch length. Details of these measurements are contained in Appendix D.

The sequence of testing the handles was randomized for each subject. The subject performed all trials on the six tests of phase 1 for a single handle in a single session. The order of the tests was randomized.

The experimental design for this phase was a three factor factorial one with a blocking on subjects. The factors were handle shape with 9 levels, handle size with four levels, and gender with two levels. Handle shape,

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handle size and gender were considered fixed factors and subjects and replications random factors. Subjects were nested in gender. A total of three replicates was run. For those analyses conducted on the data of only one sex, gender was not a factor. Twenty subjects (ten male and ten female) were used for all tests of phase 1. Additionally, analyses of covariance were conducted to evaluate the significance of anthropometric measurements in maximum force capabilities.

## IV.A.   Thrust Push

### IV.A.1   Thrust Push Method

This test measures the maximum push on a horizontal handle, as is shown in Figure IV-A-1. The action of pushing (trying to move the handle forward to a position in front of the body) is similar to the activity of sticking or jabbing a knife point first, with the knife in either of the slicing positions, into a carcass. As can be seen from Figure IV-A-1, the force measuring device (a cable tensiometer) was attached to the rear of handle such that it resisted the forward movement.

### IV.A. 2   Thrust Push Results

The results of the analyses of variance on all 36 handles are contained in Tables IV-A-1, 4 and 7 for the male subjects, female subjects and all subjects, respectively. These results are identical in the terms significant for the males and for the females. In particular, the handle shape, the handle size, and all terms involving subjects were significant. Of note is the lack of significance of the handle shape and size interaction.

The analysis for all subjects is in Table IV-A-7. With the exception of the gender-shape and the gender-shape-size interaction terms, all terms of the model are significant.

The Tukey test on handle shape for male subjects (Table IV-A-2) showed a significant difference between the circular (C) and the triangular (T) shapes only. In examining the significant differences between the handle size means (Table IV-A-3), the force exerted using the 7 cm handles was significantly less than for the 9, 11, and 13 cm handles. The force was significantly less for the 9 cm handles than for the 13 cm handles. There was no difference between the 9 and 11 cm handles or between the 11 and 13 cm handles.

Although the analysis of variance indicated a significant difference between the handle shapes for females on the thrust push task (Table IV-A-4), the Tukey test (Table IV-A-5) was not sensitive enough to determine what the differences are. For the factor of size the forces, exerted on the 7 cm handles by females were significantly less than for the 13, 11 and 9 cm handles - which did not differ among themselves (Table IV-A-6).

For all subjects combined, the mean force exerted on the triangular (T) handles was significantly greater than that of the circular (C), square (S), and rectangular (Y) 1:1.75 ratio handles (see Table IV-A-8). There was no significant difference among the remaining handle shapes. For the factor of size, the force exerted on the 7 cm handles was significantly less than for the other sizes (Table IV-A-9).

In order to evaluate the significance of the relation of the anthropometric measurements to the maximum force in the thrust push task, an analysis of covariance was conducted. For this model all variables were considered fixed. The six most promising anthropometric measures which were used as covariates were grip strength, hand breadth, fist circumference, hand circumference, forearm circumference and finger circumfer-

erence (See Appendix D ).  The results of the analyses of covariance

for male, female and all subjects are shown in tables IV-A-10, 11, and

12, respectively.  For males covariates hand breadth, fist circumference,

forearm circumference and finger circumference were significant.  For

the females grip strength, hand breadth, fist circumference, and hand

circumference were significant.   With the data combined, grip strength,

hand breadth, forearm circumference, and finger circumference were

significant.
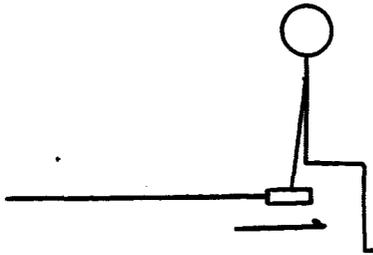
Figure IV-A-1.  Thrust Push Task

## TABLE IV-A-1

### Analysis of Variance for the Thrust Push
### Maximum Data for the Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 9421853.5 | 1 | 9421853.569 | 415.75* |
| P-Subject | R(PHS) | 203958.6 | 9 | 22662.068 | 445.05* |
| H-Handle Shape | PH | 9596.1 | 8 | 1199.510 | 2.27* |
| S-Handle Size | PS | 96007.5 | 3 | 32002.501 | 32.55* |
| PH | R(PHS) | 38.23.1 | 72 | 529.488 | 10.40* |
| PS | R(PHS) | 26543.5 | 27 | 983.093 | 19.31* |
| HS | PHS | 11948.8 | 24 | 497.866 | 1.35 |
| PHS | R(PHS) | 79423.0 | 216 | 367.699 | 7.22* |
| Replicate (PHS) | | 36662.6 | 720 | 50.920 | |

*Significant at $\alpha$ = 0.05

TABLE IV-A-2

Results of the Tukey's Test of the Handle
Shape for the Male Subjects Thrust Push Data

| Handle Shape | C | Y 1:1.75 | S 1:1 | D | O | Z 1:2 | W 1:125 | X 1:1.5 | T |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 89.30 | 91.29 | 91.56 | 91.94 | 92.99 | 93.20 | 94.30 | 95.82 | 100.21 |

TABLE IV-A-3

Results of the Tukey's Test of the Handle
Size for the Male Subjects Thrust Push Data

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 77.93 | 93.76 | 99.99 | 101.93 |

Note: All tables in this report depicting the results of Tukey's or
Scheffe's tests are constructed in this manner. The solid line
under a group of means indicates that there is no significant
difference between these means. If there is no single solid line
connecting two means, they are significantly different from each
other.

TABLE IV-A-4

Analysis of Variance for the Thrust Push
Maximum Data for the Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 4586545.2 | 1 | 4586545.19 | 755.76 |
| P-Subject | R(PHS) | 54619.2 | 9 | 6068.80 | 180.65* |
| H-Handle Shape | PH | 4030.3 | 8 | 503.79 | 2.55* |
| S-Handle Size | PS | 15526.0 | 3 | 5508.66 | 25.51* |
| PH | R(PHS) | 14229.3 | 72 | 197.63 | 5.83* |
| PS | R(PHS) | 5830.5 | 27 | 215.95 | 6.43* |
| HS | · PHS | 4935.9 | 24 | 205.66 | 1.01 |
| PHS | R(PHS) | 44084.3 | 216 | 204.09 | 6.08* |
| Replicate (PHS) | | 24186.4 | 720 | 33.59 | . |

*Significant at $\alpha = 0.05$

TABLE IV-A-5

Results of the Tukey's Test for Handle
Shape for Thrust Push Data for Female Subjects

| Handle Shape | C | S 1:1 | X 1:1.5 | D | Y 1:1.75 | T | W 1:1.25 | Z 1:2 | O |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 63.02 | 63.10 | 63.15 | 64.07 | 64.31 | 66.27 | 66.87 | 67.84 | 67.89 |

TABLE IV-A-6

Results of the Tukey's Test for Handle
Size for Thurst Push Data for Female Subjects

| Handle Size (cm) | 7 | 13 | 11 | 9 |
|---|---|---|---|---|
| | 58.46 | 66.75 | 67.22 | 68.23 |

## TABLE IV-A-7

### Analysis of Variance for the Thrust Push
### Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 13577916.5 | 1 | 0.13578D 08 | 945.18 |
| G-Gender | P(G) | 430482.2 | 1 | 0.43048D 06 | 29.97* |
| H-Handle Shape | PH(G) | 9046.6 | 8 | 1130.8 | 3.11* |
| S-Handle Size | PS(G) | 91914.3 | 3 | 30638. | 51.10* |
| P-Subject (G) | R(GPHS) | 258577.8 | 18 | 14365. | 339.96* |
| GH | PH(G) | 4579.8 | 8 | 572.47 | 1.57 |
| GS | PS(G) | 20619.2 | 3 | 6873.1 | 11.46* |
| HS | PHS(G) | 11272.9 | 24 | 469.70 | 1.64* |
| PH(G) | R(GPHS) | 52352.4 | 144 | 363.56 | 8.60* |
| PS(G) | P(GPHS) | 32374.0 | 54 | 599.52 | 14.19* |
| GHS | PHS(G) | 5611.8 | 24 | 233.83 | 0.82 |
| PHS(G) | R(GPHS) | 123507.2 | 432 | 285.90 | 6.77* |
| R-Replicate (GPHS) | | 60849.0 | 1440 | 42.255 | |

*significant at $\alpha$ = 0.05

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## TABLE IV-A-8

### Results of the Tukey's Test for the Handle Shape Thrust Push Data for Male-Female Subjects

| Handle Shape | C | S 1:1 | Y 1:1.75 | D | X 1:1.5 | O | Z 1:2 | W 1:1.25 | T |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 76.16 | 77.33 | 77.80 | 78.00 | 79.48 | 80.44 | 80.52 | 80.59 | 83.24 |

## TABLE IV-A-9

### Results of the Tukey's Test for the Handle Size Thrust Push Data for Male-Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 68.19 | 81.00 | 83.61 | 84.34 |

## TABLE IV-A-10

### Analysis of Covariance for Thrust Push
### Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 4146.5625 | 1 | 4146.56 | 13.55* |
| H-Shape | 9595.5625 | 8 | 1199.45 | 3.92* |
| S-Size | 96006.0000 | 3 | 32002.00 | 104.59* |
| HS | 11949.8125 | 24 | 497.91 | 1.63* |
| Covariates | 67037.4375 | 6 | 11172.91 | 36.52* |
| Grip Strength | 26.10 | 1 | 26.10 | 0.09 |
| Hand Breadth | 11851.3398 | 1 | 11851.34 | 38.73* |
| Fist Circum. | 3989.4570 | 1 | 3989.46 | 13.04* |
| Hand " | 7.3819 | 1 | 7.38 | 0.02 |
| Forearm " | 2686.9160 | 1 | 2686.92 | 8.78* |
| Finger " | 1986.2871 | 1 | 1986.29 | 6.49* |
| Replicate(HS) | 317592.1875 | 1038 | 305.9653 | 6.49* |

*Significant at $\alpha$ = 0.05

# TABLE IV-A-11

## Analysis of Covariance for Thrust Push
## Data for Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|---------------|--------------------|-------------|---|
| Mean | 1812.7500 | 1 | 1812.75 | 17.56* |
| H-Shape | 4030.0625 | 8 | 503.76 | 4.88* |
| S-Size | 16525.2500 | 3 | 5503.41 | 53.37* |
| HS | 4936.5625 | 24 | 205.69 | 1.99* |
| Covariates | 35786.7500 | 6 | 5964.46 | 57.79* |
| Grip Strength | 11038.2383 • | 1 | 11038.24 | 106.94* |
| Hand Breadth | 3829.4004 | 1 | 3829.40 | 37.10* |
| Fist Circum. | 547.0688 | 1 | 547.07 | 5.30* |
| Hand " | 709.1174 | 1 | 709.12 | 6.87* |
| Forearm ". | 117.0139 | 1 | 117.01 | 1.13 |
| Finger " | 0.1081 | 1 | 0.11 | 0.00 |
| Replicate(HS) | 107137.1250 | 1038 | 103.22 | |

*Significant at $\alpha$ = 0.05

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TABLE IV-A-12

## Analysis of Covariance for Thrust Push
## Data for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 5066.8750 | 1 | 5066.88 | 23.6651* |
| G-Gender | 7116.1250 | 1 | 7116.13 | 33.2363* |
| H-Shape | 9046.4375 | 8 | 1130.80 | 5.2815* |
| S-Size | 91912.0000 | 3 | 30637.33 | 143.0935* |
| GH | 4802.1875 | 8 | 600.27 | 2.8036* |
| GS | 20849.4375 | 3 | 6949.81 | 32.4595* |
| HS | 11269.8125 | 24 | 469.58 | 2.1932* |
| GHS | 5393.4375 | 24 | 224.73 | 1.0496 |
| Covariates | 82273.9375 | 6 | 13712.32 | 64.0442* |
| Grip Strength | 7008.2695 | 1 | 7008.27 | 32.7325* |
| Hand Breadth | 11975.0352 | 1 | 11975.04 | 55.9301* |
| Fist Circum. | 575.1233 | 1 | 575.12 | 2.6861 |
| Hand " | 292.4089 | 1 | 292.41 | 1.3657 |
| Forearm " | 1904.6682 | 1 | 1904.67 | 8.8959* |
| Finger " | 4205.5898 | 1 | 4205.59 | 19.6424* |
| Replicate(GHS) | 445771.0625 | 2082 | 214.11 | |

Significant at $\alpha = 0.05$

IV.B. Thrust Pull

IV.B.1 Thrust Pull Method

This test is very similar to the thrust push test except that the force is applied in the opposite direction to a horizontal handle in an attempt to move it backward. Once again the cable tensiometer resists actual movement and measures the force (see Figure IV-B-2).

IV.B.2 Thrust Pull Results

The results of the analyses of variance on all 36 handles are contained in Tables IV-B-1, 4 and 7 for the male subjects, female subjects, and for all subjects, respectively. For the male subjects the only term in the model not found to be significant was handle shape. Handle size, the shape-size interaction and all terms involving the subject factor were significant.

For female subjects, the handle shape term and the handle size term as well as all terms involving subjects were significant. Of importance is the lack of significance of the shape-size interaction.

In analyzing the data for all subjects, it was found that all terms except the gender-size interaction and the gender-shape-size interaction terms were significant.

In analyzing the differences between the means for the four sizes for males on the thrust pull task, the Tukey test showed that the 7 cm handles had significantly less force exerted on them than on the other sizes (Table IV-B-2). The force on the 9 cm handles was significantly less than that on the 11 and 13 cm handles- which did not differ significantly. In examining the handle shape-size interaction term for the males' data, the Scheffe's test (Table IV-B-3) was not sufficiently sensitive to determine what the particular differences were.

For the female subjects, the force exerted on the 1:2 ratio rectangular handle (Z) was shown to be significantly greater than that on the circular (C), circular with one flat side (D), and the square (S) handles by the Tukey test (Table IV-B-5). In evaluating the differences in force due to size (Table IV-B-6), the 7 cm handles were significantly lower than the others (which were statistically the same).

In analyzing the differences among the means of the forces exerted by all subjects on the handle shapes, the triangular (T) and rectangular (Z) (1:2 ratio) handles were significantly greater than those exerted on the circular (C) and square (S) handles (Table IV-B-8). Differences in force due to size existed between the 7 cm and all other sizes, 9 cm and the 11 cm and 13 cm handles, but not between 11 cm and 13 cm handles (Table IV-B-9). The differences for the handle shape-size interaction means, as shown by the Scheffe's test, are shown in Table IV-B-10. The strong effect of size can be observed in this table.

As with the thrust push analyses of covariance with the same six covariates were conducted for the thrust pull task data. The results of these analyses are contained in Tables IV-B-11, 12, and 13 for male, female, and all subjects, respectively. For male subjects only the covariate of hand circumference was found to be not significant. All covariates for the female subjects were significant. The results for the combined data were the same as for the male subjects above.
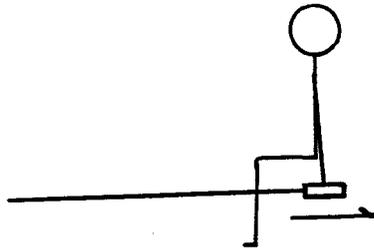
Figure IV-B-1. Thrust-Pull Task

## TABLE IV-B-1

### Analysis of Variance for the Thrust Pull
### Maximum Force for Male Subjects

| Source | Error Term | Sum of Squares | D.F.. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 9183718.7 | 1 | 9183718.716 | 339.67* |
| P-Subject | R(PHS) | 243333.4 | 9 | 27037.047 | 647.54* |
| H-Handle Shape | PH | 4753.2 | 8 | 594.148 | 2.05 |
| S-Handle Size | PS | 59368.5 | 3 | 19789.490 | 29.19* |
| PH | R(PHS) | 20882.9 | 72 | 290.041 | 6.95* |
| PS | R(PHS) | 18301.7 | 27 | 677.839 | 16.23* |
| HS | PHS | 8411.2 | 24 | 350.467 | 1.59* |
| PHS | R(PHS) | 47596.8 | 216 | 220.356 | 5.28* |
| R-Replicate (PHS) | · | 30062.5 | 720 | 41.753 | |

*Significant at $\alpha$ = 0.05.

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## TABLE IV-B-2

### Results of the Tukey's Test of the Handle
### Size for the Males Subjects Thrust Pull Data

| Handle Size (cm) | 7 | 9 | 13 | 11 |
|---|---|---|---|---|
| Mean Newtons | 80.34 | 91.60 | 98.06 | 98.86 |

TABLE IV-B-3

Results of the Scheffe's Test for the
Handle Shape and Size Thrust Pull for
Male Subjects

| Handle | | Mean |
|--------|------|---------|
| Shape | Size | Newtons |
| Y | 7 | 77.13 |
| O | 7 | 78.85 |
| Z | 7 | 79.07 |
| T | 7 | 80.68 |
| C | 7 | 81.22 |
| D | 7 | 81.22 |
| S | 7 | 81.44 |
| X | 7 | 81.65 |
| W | 7 | 81.76 |
| D | 9 | 85.96 |
| C | 9 | 87.36 |
| S | 13 | 88.93 |
| C | 13 | 90.05 |
| W | 9 | 90.59 |
| X | 9 | 90.59 |
| O | 9 | 91.45 |
| S | 9 | 91.67 |
| O | 11 | 93.82 |
| T | 9 | 95.55 |
| C | 11 | 95.55 |
| Z | 9 | 95.55 |
| Y | 9 | 95.66 |
| W | 13 | 95.87 |
| X | 11 | 97.16 |
| S | 11 | 97.98 |
| D | 11 | 98.78 |
| Y | 11 | 99.53 |
| D | 13 | 99.64 |
| Z | 13 | 99.64 |
| Y | 13 | 99.75 |
| Z | 11 | 100.61 |
| O | 13 | 100.72 |
| W | 11 | 102.33 |
| X | 13 | 103.63 |
| T | 11 | 104.06 |
| T | 13 | 104.27 |

TABLE IV-B-4

Analysis of Variance for the Thrust Pull.
Maximum Force for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 5121462.5 | 1 | 5121462.49 | 632.84* |
| P-Subject | R(PHS) | 72834.9 | 9 | 8092.77 | 249.01* |
| H-Handle Shape | PH | 4252.4 | 8 | 531.55 | 2.77* |
| S-Handle Size | PS | 10254.2 | 3 | 3418.05 | 11.32* |
| PH | R(PHS) | 13796.7 | 72 | 191.621 | 5.90* |
| PS | R(PHS) | 8153.9 | 27 | 302.00 | 9.29* |
| HS | PHS | 5592.9 | 24 | 233.04 | 1.33 |
| PHS | R(PHS) | 37899.4 | 216 | 175.46 | 5.40* |
| R-Replicate (PHS) | | 23399.7 | 720 | 32.50 | |

*Significant at $\alpha$ = 0.05.

TABLE IV-B-5

Results of the Tukey's Test for Handle
Shape for Thrust Pull Data for Female Subjects

| Handle Shape | C | D | S 1:1 | Y 1:1.75 | X 1:1.5 | W 1:1.25 | O | T | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 66.36 | 66.73 | 66.81 | 67.94 | 69.16 | 69.29 | 70.37 | 70.42 | 72.68 |

TABLE IV-B-6

Results of the Tukey's Test for Handle Size
for Thrust Push Data for Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| | 63.57 | 70.19 | 70.47 | 71.22 |

Note: All tables in this report depicting the results of Tukey's or
Scheffe's tests are constructed in this manner. The solid line
under a group of means indicates that there is no significant
difference between these means. If there is no single solid
line connecting two means, they are significantly different
from each other.

# TABLE IV-B-7

## Analysis of Variance for the Thrust Pull
## Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 14010729.6 | 1 | 0.14011D 08 | 797.65* |
| G—Gender | P(G) | 294451.6 | 1 | 0.29445D 06 | 16.76* |
| H—Handle Shape | PH(G) | 7571.6 | 8 | 946.45 | 3.93* |
| S—Handle Size | PS(G) | 58199.6 | 3 | 19400. | 39.60* |
| P—Subject (G) | R(GPHS) | 316168.3 | 18 | 17565. | 473.11* |
| GH | PH(G) | 1434.0 | 8 | 179.25 | 0.74 |
| GS | PS(G) | 11423.1 | 3 | 3807.7 | 7.77* |
| HS | PHS(G) | 9330.0 | 24 | 388.75 | 1.96* |
| PH(G) | R(GPHS) | 34679.7 | 144 | 240.83 | 6.49* |
| PS(G) | R(GPHS) | 25455.6 | 54 | 489.92 | 13.20* |
| GHS | PHS(G) | 4674.0 | 24 | 194.75 | 0.98 |
| PHS(G) | R(GPHS) | 85496.2 | 432 | 197.91 | 5.33* |
| R—Replicate (GPHS) | | 53462.2 | 1440 | 37.127 | |

*Significant at $\alpha$ = 0.05

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TABLE IV-B-8

Results of the Tukey's Test for the Handle
Shape Thrust-Pull Data for Male-Female Subjects

| Handle Shape | C | S 1:1 | D | Y 1:1.75 | O | W 1:1.25 | X 1:1.5 | Z 1:2 | T |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 77.45 | 78.41 | 79.07 | 80.48 | 80.79 | 80.96 | 81.21 | 83.20 | 83.28 |

TABLE IV-B-9

Results of the Tukey's Test for the Handle
Size Thrust Pull Data for Male and Female Subjects

| Handle Size (cm) | 7 | 9 | 13 | 11 |
|---|---|---|---|---|
| Mean Newtons | 71.95 | 80.89 | 84.64 | 84.66 |

TABLE IV-B-10

Results of the Scheffe's Test for the
Handle Shape and Size Thrust Pull Data
for Male and Female Subjects

| Handle | | Mean |
|--------|------|---------|
| Shape | Size | Newtons |
| Y | 7 | 68.24 |
| O | 7 | 70.77 |
| C | 7 | 71.31 |
| S | 7 | 71.58 |
| X | 7 | 71.85 |
| Z | 7 | 72.60 |
| T | 7 | 73.36 |
| W | 7 | 73.84 |
| D | 7 | 74.00 |
| D | 9 | 77.50 |
| S | 13 | 77.78 |
| C | 13 | 78.20 |
| C | 9 | 78.31 |
| X | 9 | 79.87 |
| W | 9 | 79.98 |
| S | 9 | 80.79 |
| O | 9 | 81.17 |
| D | 11 | 81.60 |
| Y | 9 | 81.71 |
| C | 11 | 81.92 |
| W | 13 | 82.67 |
| X | 11 | 83.11 |
| D | 13 | 83.16 |
| O | 11 | 83.43 |
| S | 11 | 83.48 |
| Z | 9 | 84.24 |
| T | 9 | 84.40 |
| Y | 13 | 85.15 |
| Z | 11 | 86.66 |
| Y | 11 | 86.82 |
| W | 11 | 87.36 |
| T | 11 | 87.63 |
| T | 13 | 87.74 |
| O | 13 | 87.79 |
| Z | 13 | 89.30 |
| X | 13 | 90.00 |

## TABLE IV-B-11

### Analysis of Covariance for Thrust Pull
### Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 6764.5625 | 1 | 6764.46 | 30.39* |
| H-Shape | 4753.2500 | 8 | 594.16 | 2.67* |
| S-Size | 59368.3750 | 3 | 19789.46 | 88.92* |
| HS | 8410.6875 | 24 | 350.45 | 1.57* |
| Covariates | 129088.8750 | 6 | 21514.81 | 96.67* |
| Grip Strength | 4207.6133 | 1 | 4207.61 | 18.91* |
| Hand Breadth | 19346.5469 | 1 | 19346.55 | 86.93* |
| Fist Circum. | 8894.5781 | 1 | 8894.58 | 39.96* |
| Hand " | 127.6477 | 1 | 127.65 | 0.57 |
| Forearm " | 4997.3984 | 1 | 4997.40 | 22.45* |
| Finger " | 1514.4255 | 1 | 1514.43 | 6.80* |
| Replicate(HS) | 231022.5625 | 1038 | 222.57 | |

*Significant at $\alpha = 0.05$

## TABLE IV-B-12

### Analysis of Covariance for Thrust Pull Data
### for Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 6274.8125 | 1 | 6274.81 | 69.81* |
| H-Shape | 4252.3750 | 8 | 531.55 | 5.91* |
| S-Size | 10253.6875 | 3 | 3417.90 | 38.03* |
| HS | 5592.8125 | 24 | 233.03 | 2.59* |
| Covariates | 62755.4375 | 6 | 10459.24 | 116.36* |
| Grip Strength | 13294.6914 | 1 | 13294.69 | 147.91* |
| Hand Breadth | 4147.6836 | 1 | 4147.68 | 46.14* |
| Fist Circum. | 401.8853 | 1 | 401.89 | 4.47* |
| Hand " | 1163.4063 | 1 | 1163.41 | 12.94* |
| Forearm " | 1696.3696 | 1 | 1696.37 | 18.87* |
| Finger " | 514.9258 | 1 | 514.93 | 5.73* |

Significant at $\alpha = 0.05$

# TABLE IV-B-13

## Analysis of Covariance for Thrust Pull
## Data for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|-------|-------|-------|-------|
| Mean | 17698.6250 | 1 | 17698.63 | 106.6637* |
| G-Gender | 2164.5625 | 1 | 2164.56 | 13.0451* |
| H-Shape | 7571.6250 | 8 | 946.45 | 5.7040* |
| S-Size | 58199.0525 | 3 | 19399.69 | 116.9155* |
| GH | 1289.5625 | 8 | 161.20 | 0.9715 |
| GS | 11276.4375 | 3 | 3758.81 | 22.6531* |
| HS | 9326.9375 | 24 | 388.62 | 2.3421* |
| GHS | 4811.2500 | 24 | 200.47 | 1.2082 |
| Covariates | 171151.0000 | 6 | 28525.16 | 171.9117* |
| Grip Strength | 22111.8203 | 1 | 22111.82 | 133.2606* |
| Hand Breadth | 17851.7266 | 1 | 17851.73 | 107.5864* |
| Fist Circum. | 1641.9163 | 1 | 1641.92 | 9.8953* |
| Hand " | 61.5250 | 1 | 61.53 | 0.3708 |
| Forearm " | 6250.0938 | 1 | 6250.09 | 37.6672* |
| Finger " | 4632.4922 | 1 | 4632.49 | 27.9185* |
| Replicate(GHS) | 345464.500 | 2082 | 165.93 | |

*Significant at $\alpha = 0.05$

## IV.C.  Orthogonal Push

### IV.C.1  Orthogonal Push Method

This test measures the maximum push on a vertical handle, as is
shown in Figure IV-C-1.  The test forces on the hand are similar to those
encountered when cutting with the knife in the slicing position or the
stabbing position (see Figure I-1).

### IV.C. 2  Orthogonal Push Results

The results of the analyses of variance of all 36 handles are con-
tained in Tables IV-C-1, 4 and 6 for the male subjects, the female sub-
jects, and for all subjects, respectively.  The results for the male
subjects show significance for all factors and interactions except the
shape-size interaction.

For the female subjects the size term and the shape-size interaction
term were not found to be significant.

In analyzing the combined data of all subjects on the orthogonal
push task, the gender-shape, the gender-size, the shape-size, and the
gender-shape-size interaction terms were found to be not significant.
All other terms were significant at $\alpha = 0.05$.

The Tukey test on handle shape (Table IV-C-2) showed that the force
exerted by males with the circular (C) handles was significantly greater
than with the triangular (T) or the 1:2 ratio rectangular (Z) handles.
In testing differences in force exerted by males due to handle size, 9 cm
was shown to be superior to 13 cm (Table IV-C-3).

With female subjects significantly more force was exerted in the
orthogonal push on the circular (C) handle than on the triangular (T)
handles (Table IV-C-5).

For all subjects' data the evaluation of forces as a function of

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shape revealed that the circular (C) handles were significantly better than the triangular (T) and the 1:2 (Z) and 1:1.75 (Y) rectangular handles. Also, the circular (O) with two flat sides handles were significantly better than the triangular (T) and 1:2 ratio (Z) rectangular handles (Table IV-C-7). The evaluation of differences due to size (Table IV-C-8) showed the force exerted with the 13 cm handle significantly less than the 9 cm and the 11 cm but not than the 7 cm handles. Also, the 7, 11, and 9 cm handles were shown to not differ significantly from each other on the orthogonal push.

With the same six covariates as were used with the thrust data, analyses of covariance were conducted for the vertical push task data. The results of these analyses are contained in Tables IV-C-9, 10 and 11, for male, female, and all subjects data, respectively. For males alone, females alone, and all subjects combined data, all covariates were significant at the $\alpha = 0.05$ level.
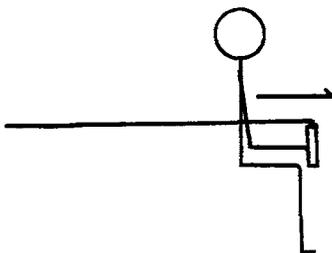
Figure IV-C-1.  Orthogonal Push Task

## TABLE IV-C-1

### Analysis of Variance for the Orthogonal Push
### Maximum Force for Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|--------|------------|----------------|------|-------------|---|
| Mean | P | 30168188.3 | 1 | 0.30168D 08 | 329.25* |
| P-Subject | R(PHS) | 824637.3 | 9 | 91626. | 1037.41* |
| H-Handle Shape | PH | 14030.1 | 8 | 1753.8 | 3.22* |
| S-Handle Size | PS | 7955.0 | 3 | 2651.7 | 4.05* |
| PH | R(PHS) | 39180.7 | 72 | 544.18 | 6.16* |
| PS | R(PHS) | 17698.5 | 27 | 655.50 | 7.42* |
| HS | PHS | 14103.4 | 24 | 587.64 | 1.00 |
| PHS | R(PHS) | 127247.2 | 216 | 589.11 | 6.67* |
| R-Replicate (PHS) | | 63592.1 | 720 | 88.322 | |

*Significant at $\alpha$ = 0.05.

# TABLE IV-C-2

### Results of the Tukey's Test of the Handle
### Shape for the Male Subjects Orthogonal Push Data

| Handle Shape | T | Z 1:2 | Y 1:1.75 | D | S 1:1 | X 1:1.5 | W 1:1.25 | O | C |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 161.07 | 163.20 | 164.22 | 166.16 | 167.26 | 169.50 | 169.52 | 170.36 | 172.92 |

# TABLE IV-C-3

### Results of the Tukey's Test of the Handle
### Size for the Male Subjects Orthogonal Push Data

| Handle Size (cm) | 13 | 7 | 11 | 9 |
|---|---|---|---|---|
| Mean Newtons | 162.80 | 167.03 | 168.71 | 169.99 |

## TABLE IV-C-4

## Analysis of Variance for the Orthogonal Push
## Maximum Force for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 10111349.0 | 1 | 0.10111D 08 | 392.73* |
| P-Subject | R(PHS) | 231718.1 | 9 | 25746. | 448.40* |
| H-Handle Shape | PH | 8298.2 | 8 | 1037.3 | 2.78* |
| S-Handle Size | PS | 2170.4 | 3 | 723.48 | 2.32 |
| PH | R(PHS) | 25900.4 | 72 | 373.62 | 6.51* |
| PS | R(PHS) | 8425.2 | 27 | 312.05 | — 5.43* |
| HS | PHS | 7666.6 | 24 | 319.44 | 1.14 |
| PHS | R(PHS) | 60476.8 | 216 | 279.99 | 4.88* |
| R-Replicate (PHS) | | 41341.1 | 720 | 57.418 | |

*Significant at $\alpha$ = 0.05

TABLE IV-C-5

Results of the Tukey's Test for Handle
Shape for Orthogonal Push Data for
Female Subjects

| Handle Shape | T | X | Y | Z | W | D | S | O | C |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 93.39 | 94.12 | 94.15 | 95.04 | 95.76 | 97.16 | 97.99 | 100.23 | 101.98 |

## TABLE IV-C-6

### Analysis of Variance for the Orthogonal Push
### Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 37605193.9 | 1 | 0.37605D 08 | 640.78* |
| G-Gender | P(G) | 2674343.4 | 1 | 0.26743D 07 | 45.57* |
| H-Handle Shape | PH(G) | 19536.2 | 8 | 2442.0 | 5.32* |
| S-Handle Size | PS(G) | 8395.1 | 3 | 2798.4 | 5.78* |
| P-Subject (G) | R(GPHS) | 1056355.4 | 18 | 58686. | 805.35* |
| GH | PH(G) | 2792.1 | 8 | 349.01 | 0.76 |
| GS | PS(G) | 1730.3 | 3 | 576.78 | 1.19 |
| HS | PHS(G) | 13103.5 | 24 | 545.98 | 1.26 |
| PH(G) | R(GPHS) | 65081.2 | 144 | 458.90 | 6.30* |
| PS(G) | R(GPHS) | 25123.7 | 54 | 483.77 | 6.64* |
| GHS | PHS(G) | 8666.6 | 24 | 361.11 | 0.83 |
| PHS(G) | R(GPHS) | 187723.9 | 432 | 434.55 | 5.96* |
| R-Replicate (GPHS) | | 104933.2 | 1440 | 72.870 | |

*Significant at $\alpha = 0.05$

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TABLE IV-C-7

Results of the Tukey's Test for the
Handle Shape Orthogonal Push Data for
Male and Female Subjects

| Handle Shape | T | Z 1:2 | Y 1:1.75 | D | X 1:1.5 | S 1:1 | W 1:1.25 | O | C |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 127.23 | 129.12 | 129.18 | 131.66 | 131.81 | 132.63 | 133.14 | 135.30 | 137.45 |

TABLE IV-C-8

Results of the Tukey's Test for the
Handle Shape Orthogonal Push Data for
Male and Female Subjects

| Handle Size (cm) | 13 | 7 | 11 | 9 |
|---|---|---|---|---|
| Mean Newtons | 129.16 | 131.18 | 133.08 | 134.37 |

## TABLE IV-C-9

### Analysis of Covariance for Orthogonal Push
### Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 219292.3750 | 1 | 219292.38 | 624.77* |
| H-Shape | 14031.5625 | 8 | 1753.95 | 5.00* |
| S-Size | 7955.7500 | 3 | 2651.92 | 7.56* |
| HS | 14103.8125 | 24 | 587.66 | 1.67* |
| Covariates | 707442.4375 | 6 | 117907.06 | 335.92* |
| Grip Strength | 146676.0625 | 1 | 146676.06 | 417.88* |
| Hand Breadth | 3147.3086 | 1 | 3147.31 | 8.97* |
| Fist Circum. | 16577.7773 | 1 | 16577.78 | 47.23* |
| Hand " | 250275.8125 | 1 | 250275.81 | 713.04* |
| Forearm " | 180477.3215 | 1 | 180477.31 | 514.18* |
| Finger " | 22353.9102 | 1 | 22353.91 | 63.69* |
| Replicate (HS) | 364337.5625 | 1038 | 351.00 | |

*Significant at $\alpha = 0.05$

## TABLE IV-C-10

### Analysis of Covariance for Orthogonal Push Push Data For Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 60785.7500 | 1 | 60785.75 | 365.22* |
| H-Shape | 8298.6250 | 8 | 1037.33 | 6.23* |
| S-Size | 2170.7500 | 3 | 723.58 | 4.35* |
| HS | 7666.1875 | 24 | 319.42 | 1.92* |
| Covariates | 196052.6875 | 6 | 32675.45 | 196.33* |
| Grip Strength | 13016.4219 | 1 | 13016.42 | 78.21* |
| Hand Breadth | 14316.8359 | 1 | 14316.84 | 86.02* |
| Fist Circum. | 3366.3262 | 1 | 3366.33 | 20.23* |
| Hand " | 33646.2813 | 1 | 33646.28 | 202.16* |
| Forearm " | 792.7800 | 1 | 792.78 | 4.76* |
| Finger " | 13430.6445 | 1 | 13430.64 | 80.70* |
| Replicate(HS) | 172759.5000 | 1038 | 166.44 | |

*Significant at $\alpha = 0.05$

## TABLE IV-C-11

### Analysis of Covariance for Orthogonal Push Push Data for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 210841.5000 | 1 | 210841.50 | 538.7625* |
| G-Gender | 93450.8125 | 1 | 93450.81 | 238.7945* |
| H-Shape | 19535.1875 | 8 | 2441.90 | 6.2398* |
| S-Size | 8391.3750 | 3 | 2797.13 | 7.1475* |
| GH | 3433.2500 | 8 | 429.16 | 1.0966 |
| GS | 2240.6875 | 3 | 746.90 | 1.9085 |
| HS | 13105.6250 | 24 | 546.07 | 1.3954 |
| GHS | 8067.6875 | 24 | 336.15 | 0.8590 |
| Covariates | 626286.5000 | 6 | 104381.06 | 266.7244* |
| Grip Strength | 56490.9375 | 1 | 56490.94 | 144.3511* |
| Hand Breadth | 1805.5776 | 1 | 1805.58 | 4.6138* |
| Fist Circum. | 14070.3047 | 1 | 14070.30 | 35.9538* |
| Hand    " | 224665.4375 | 1 | 224665.44 | 574.0867* |
| Forearm " | 98840.2500 | 1 | 98840.25 | 252.5661* |
| Finger  " | 7671.5586 | 1 | 7671.56 | 19.6031* |
| Replicate(GHS) | 814778.5000 | 2082 | 391.34 | |

*Significant at $\alpha$ = 0.05

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## IV.D.  Orthogonal Pull

### IV.D.1  Orthogonal Pull Method

This test measures the maximum pull on a vertical handle, as is shown in Figure IV-D-1.  The test forces on the hand are similar to those encountered when cutting with the knife in the inverted slicing position or the inverted stabbing position  (see Figure I-1).

### IV.D.2  Orthogonal Pull Results

The results of the analyses of variance on all 36 handles are shown in Tables IV-D-1, 4, and 6 for the male subjects, the female subjects, and all subjects, respectively.  For the male subjects only the size term was not significant.  For the female subjects handle shape and shape-size interaction terms were found to not be significant.   The other terms were significant at $\alpha = 0.05$.  For the combined data of all subjects, all but three interaction terms were found to be significant. The three interaction terms found to be not significant were gender-shape, gender-size, and gender-shape-size.

For the male subjects the forces exerted on the handles in the orthogonal pull differed due to handle shape; however, the Tukey test on the shape means failed to determine which means were different (Table IV-D-2).  The same is true for the Scheffe's test on the handle shape-size interaction term means shown in Table IV-D-3.

The differences in force by female subjects due to handle size were evaluated (Table IV-D-5).  Forces on 13 cm and 11 cm handles were significantly less than those on 7 cm handles.

In evaluating the effect of handle shape using all subjects' force data on the orthogonal pull, the Tukey test showed forces on circular (C) handles were significantly less than on triangular (T) and 1:1.5 ratio  (X) rectangular handles (Table IV-D-7).  All other pairings of

handle shapes were not significantly different. Differences in size were shown (Table IV-D-8) to be significant between the 13 cm handles (low force) and the 7 cm handles (high force) only. Once again the Scheffe's test failed to determine the differences between the handle shape-size interaction means.

Analyses of covariance were conducted using the six covariates discussed in the thrust push task. Tables IV-D-10, 11, and 12 contain the results of these. For the male data the covariates of forearm circumference and finger circumference were not significant. For the females data the covariates grip strength, hand breadth, fist circumference, and forearm circumference were significant. When all of the data was analyzed together, grip strength, hand breadth, hand circumference, and forearm circumference were found to be significant.
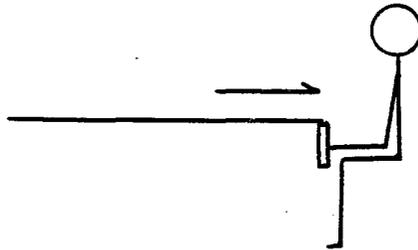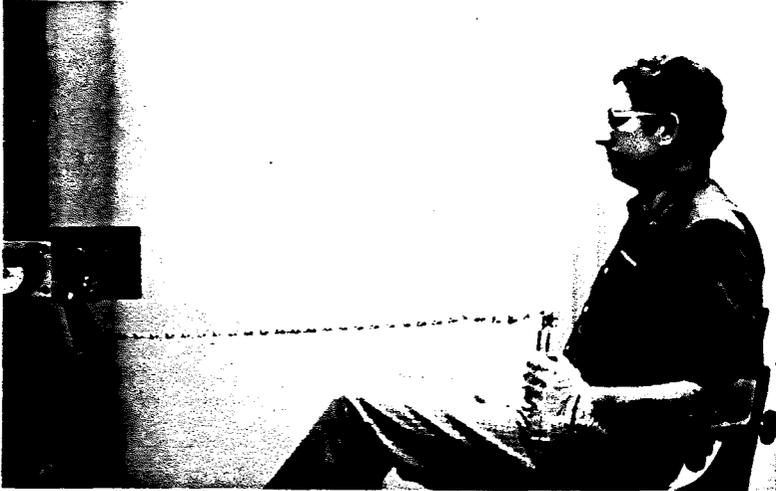
Figure IV-D-1.  Orthogonal Pull Task

TABLE IV-D-1

Analysis of Variance for the Orthogonal Pull
Maximum Force for Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 11375553.6 | 1 | 0.11376D 08 | 260.61* |
| P-Subject | R(PHS) | 392854.3 | 9 | 43650. | 1274.83* |
| H-Handle Shape | PH | 8309.8 | 8 | 1038.7 | 2.66* |
| S-Handle Size | PS | 1461.5 | 3 | 487.18 | 1.13 |
| PH | R(PHS) | 28087.8 | 72 | 390.11 | 11.39* |
| PS | R(PHS) | 11598.8 | 27 | 429.58 | 12.55* |
| HS | PHS | 12041.9 | 24 | 501.75 | 1.87* |
| PHS | R(PHS) | 58023.0 | 216 | 268.62 | 7.85* |
| R-Replicate (PHS) | | 24652.9 | 720 | 34.240 | |

*Significant at $\alpha = 0.05$

TABLE IV-D-2

**Results of the Tukey's Test of the Handle**
**Shape for the Male Subjects Orthogonal Pull Data**

| Handle Shape | C | O | S 1:1 | Z 1:2 | D | Y 1:1.75 | W 1:1.25 | T | X 1:1.5 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 98.59 | 101.12 | 101.34 | 101.45 | 101.77 | 102.28 | 103.28 | 104.76 | 109.09 |

TABLE IV-D-3

Results of the Scheffe's Test for the
Handle Shape and Size Orthogonal Push
Data for Male Subjects

| Handle | | Mean |
| Shape | Size | Newtons |
| --- | --- | --- |
| C | 13 | 91.24 |
| D | 13 | 95.87 |
| Y | 9 | 96.09 |
| S | 13 | 96.19 |
| W | 13 | 97.81 |
| Z | 7 | 98.02 |
| C | 11 | 98.24 |
| O | 11 | 99.10 |
| T | 7 | 99.10 |
| O | 7 | 99.86 |
| S | 11 | 100.07 |
| Y | 7 | 100.18 |
| Z | 13 | 100.29 |
| O | 13 | 100.93 |
| D | 9 | 101.04 |
| C | 9 | 101.26 |
| Z | 9 | 101.47 |
| D | 11 | 101.90 |
| S | 9 | 102.76 |
| C | 7 | 103.62 |
| W | 7 | 104.38 |
| W | 11 | 104.38 |
| O | 9 | 104.60 |
| Y | 11 | 104.92 |
| T | 11 | 105.13 |
| Z | 11 | 106.00 |
| S | 7 | 106.32 |
| W | 9 | 106.53 |
| T | 9 | 106.97 |
| X | 13 | 107.50 |
| T | 13 | 107.83 |
| Y | 13 | 107.94 |
| X | 9 | 108.26 |
| D | 7 | 108.26 |
| X | 11 | 109.23 |
| X | 7 | 111.38 |

TABLE IV-D-4

Analysis of Variance for the Orthogonal Pull
Maximum Force for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 5583639.3 | 1 | 5583639.29 | 851.78* |
| P-Subject | R(PHS) | 58997.2 | 9 | 6555.25 | 305.78* |
| H-Handle Shape | PH | 1826.3 | 8 | 228.29 | 1.64 |
| S-Handle Size | PS | 3270.7 | 3 | 1090.23 | 4.74* |
| PH | R(PHS) | 10005.6 | 72 | 138.97 | 6.48* |
| PS | R(PHS) | 6216.0 | 27 | 230.22 | 10.74* |
| HS | PHS | 3837.1 | 24 | 159.88 | 1.34 |
| PHS | R(PHS) | 25819.0 | 216 | 119.53 | 5.58* |
| R-Replicate (PHS) | | 15435.0 | 720 | 21.44 | |

*Significant at $\alpha = 0.05$

TABLE IV-D-5

Results of the Tukey's Test for Handle
Size for Orthogonal Pull Data for
Female Subjects

| Handle Size (cm) | 13 | 11 | 9 | 7 |
|---|---|---|---|---|
| Mean Newtons | 70.12 | 70.35 | 73.26 | 73.48 |

## TABLE IV-D-6

### Analysis of Variance for the Orthogonal Pull Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|--------|-----------|----------------|------|-------------|-----|
| Mean | P(G) | 16449351.04 | 1 | 0.16449D 08 | 655.28* |
| G-Gender | P(G) | 509841.87 | 1 | 0.50984D 06 | 20.31* |
| H-Handle Shape | PH(G) | 6237.55 | 8 | 779.68 | 2.95* |
| S-Handle Size | PS(G) | 3822.26 | 3 | 1274.1 | 3.86* |
| P-Subject (G) | R(GPHS) | 451851.55 | 18 | 25103. | 901.72* |
| GH | PH(G) | 3898.62 | 8 | 487.33 | 1.84 |
| GS | PS(G) | 909.96 | 3 | 303.32 | 0.92 |
| HS | PHS(G) | 10233.89 | 24 | 426.41 | 2.20* |
| PH(G) | R(GPHS) | 38093.40 | 144 | 264.54 | 9.50* |
| PS(G) | R(GPHS) | 17814.71 | 54 | 329.90 | 11.85* |
| GHS | PHS(G) | 5645.18 | 24 | 235.22 | 1.21 |
| PHS(G) | R(GPHS) | 83841.97 | 432 | 194.08 | 6.97* |
| R-Replicate(GPHS) | | 40087.90 | 1440 | 27.839 | |

*Significant at $\alpha = 0.05$

TABLE IV-D-7

Results of the Tukey's Test for the
Handle Shape Orthogonal-Pull Data
for Male and Female Subjects

| Handle Shape | C | D | Z 1:2 | Y 1:1.75 | S 1:1 | O | W 1:1.25 | T | X 1:1.5 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 84.55 | 86.36 | 86.40 | 86.43 | 86.90 | 87.07 | 87.56 | 89.82 | 90.35 |

TABLE IV-D-8

Results of the Tukey's Test for the
Handle Size Orthogonal Pull Data
for Male and Female Subjects

| Handle Size (cm) | 13 | 11 | 9 | 7 |
|---|---|---|---|---|
| Mean Newtons | 85.32 | 86.79 | 88.24 | 88.72 |

## TABLE IV-D-9

### Results of the Scheffe's Test for
### Handle Shape and Size Orthogonal Pull
### for Male and Female Subjects

| Handle | | Mean |
|--------|------|---------|
| Shape | Size | Newtons |
| C | 13 | 79.77 |
| D | 13 | 81.60 |
| Y | 9 | 82.19 |
| C | 11 | 82.35 |
| W | 13 | 83.27 |
| S | 13 | 83.97 |
| Z | 13 | 83.97 |
| S | 11 | 84.29 |
| O | 13 | 85.26 |
| Y | 7 | 85.53 |
| D | 11 | 85.96 |
| Z | 9 | 86.12 |
| O | 11 | 86.23 |
| T | 7 | 86.82 |
| W | 11 | 87.14 |
| D | 9 | 87.25 |
| Z | 7 | 87.25 |
| C | 9 | 87.31 |
| O | 7 | 87.58 |
| Z | 11 | 88.28 |
| Y | 13 | 88.71 |
| X | 11 | 88.76 |
| T | 11 | 88.76 |
| S | 9 | 88.76 |
| C | 7 | 88.76 |
| O | 9 | 88.98 |
| Y | 11 | 89.30 |
| W | 7 | 89.46 |
| X | 9 | 90.11 |
| W | 9 | 90.38 |
| S | 7 | 90.59 |
| D | 7 | 90.65 |
| T | 13 | 90.65 |
| X | 13 | 90.70 |
| X | 7 | 91.83 |
| T | 9 | 93.07 |

# TABLE IV-D-10

## Analysis of Covariance for Vertical Pull
### Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 23973.2500 | 1 | 23973.25 | 95.00* |
| H-Shape | 8309.5000 | 8 | 1038.69 | 4.12* |
| S-Size | 1461.5000 | 3 | 487.17 | 1.93 |
| HS | 12042.2500 | 24 | 501.76 | 1.99* |
| Covariates | 253301.1250 | 6 | 42216.85 | 167.29* |
| Grip Strength | 43002.4688 | 1 | 43002.47 | 170.40* |
| Hand Breadth | 17662.9570 | 1 | 17662.96 | 69.99* |
| Fist Circum. | 7695.9805 | 1 | 7695.98 | 30.50* |
| Hand " | 8930.9609 | 1 | 8930.96 | 35.39* |
| Forearm " | 297.7046 | 1 | 297.70 | 1.18 |
| Finger " | 110.3197 | 1 | 110.32 | 0.44 |
| Replicate (HS) | 261951.1250 | 1038 | 252.36 | |

*Significant at $\alpha = 0.05$

## TABLE IV-D-11

### Analysis of Covariance for Vertical
### Pull Data for Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 239.3125 | 1 | 239.31 | 3.59 |
| H-Shape | 1826.1875 | 8 | 228.27 | 3.43 |
| S-Size | 3270.6250 | 3 | 1090.21 | 16.38* |
| HS | 3836.9375 | 24 | 159.87 | 2.40* |
| Covariates | 47351.1875 | 6 | 7891.86 | 118.54* |
| Grip Strength | 7060.0586 | 1 | 7060.06 | 106.05* |
| Hand Breadth | 4114.1406 | 1 | 4114.14 | 61.80* |
| Fist Circum. | 3614.3477 | 1 | 3614.35 | 54.29* |
| Hand      " | 33.2437 | 1 | 33.24 | 0.50 |
| Forearm " | 3106.88 | 1 | 3106.88 | 46.67* |
| Finger   " | 114.1852 | 1 | 114.19 | 1.72 |
| Replicate(HS) | 69102.7500 | 1038 | 66.57 | |

*Significant at $\alpha$ = 0.05

TABLE IV-D-12

Analysis of Covariance for Vertical
Pull for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 8141.8750 | 1 | 8141.88 | 47.2394* |
| G-Gender | 8.6875 | 1 | 8.69 | 0.0504 |
| H-Shape | 6237.3750 | 8 | 779.67 | 4.5237* |
| S-Size | 3822.6875 | 3 | 1274.23 | 7.3931* |
| GH | 3903.3750 | 8 | 487.92 | 2.8309* |
| GS | 915.0625 | 3 | 305.02 | 1.7697 |
| HS | 10233.6250 | 24 | 426.40 | 2.4740* |
| GHS | 5640.1875 | 24 | 235.01 | 1.3635 |
| Covariates | 273217.8125 | 6 | 45536.30 | 264.2031* |
| Grip Strength | 80503.7500 | 1 | 80503.75 | 467.0854* |
| Hand Breadth | 13480.7344 | 1 | 13480.73 | 78.2157* |
| Fist Circum. | 200.5581 | 1 | 200.56 | 1.1636 |
| Hand " | 1403.1270 | 1 | 1403.13 | 8.1410* |
| Forearm " | 11371.0586 | 1 | 11371.06 | 65.9753* |
| Finger " | 289.3076 | 1 | 289.31 | 1.6786 |
| Replicate(GHS) | 358839.6875 | 2082 | 172.35 | |

*Significant at $\alpha = 0.05$

## IV.E. Wrist Extension

### IV.E.1 Wrist Extension Method

In the wrist extension torque test the standing subject attempted to rotate or twist the handle, as is shown in Figure IV-E-1. Once again, this was a maximal exertion by the subject.

### IV.E.1 Wrist Extension Results

The results of the analyses of variance on all 36 handles are contained in Tables IV-E-1, 5 and 9 for the male subjects, the female subjects and for all subjects, respectively. All terms in these models for wrist extension were found to be significant.

The results of the Tukey test on male data for the wrist extension task are shown in Table IV-E-2. Circular (C) handles were significantly lower than all other shapes in the amount of torque exerted. With the handle shapes arranged in ascending order according to torque on this task, no four handle shapes in sequence are statistically the same. There is a break between the 5th and 6th handle shapes (rectangular ratio 1:1.25 (W) and rectangular ration 1:1.50(X)) such that those above are statistically different from all of those below. Also of interest is the fact that these handle shapes are, with the exception of the triangular (T) handle shape, in ascending order according to the ratio of width to height.

The test on torque means assocated with handle sizes showed all are significantly different from each other (Table IV-E-3). The mean torque for the 7 cm handles was lowest and increased significantly from 7 to 9 cm, from 9 to 11 cm and from 11 to 13 cm.

The Scheffe's test on the handle shape-size interaction means is shown in Table IV-E-4. This table gives a good idea as to the progression

of handle shape-size combinations and the relative torque (extension) which can be exerted on them.

The results of the Tukey test on female data on the wrist extension test are shown in Table IV-E-6 and are similar to those of the male subjects. The circular (C) handles had significantly less torque exerted on them than all other handles. The ratio 1:2.00 rectangular (Z) handle for females had significantly more torque exerted on it than all other models except the ratio 1:1.75 rectangular (Y) handles.

In examining the effect of handle size on wrist extension torque (Table IV-E-7) all sizes were significantly different from each other.

The Scheffe's test in Table IV-E-8 shows the differences in handle shape-size combinations on the extension torque.

The results of the Tukey test on handle shape for all of the data are very similar to those of males and females alone (Table IV-E-10). The torque on circular handles was significantly less than for other handles and that for the 1:2.00 ratio rectangular (Z) handles was significantly greater than for the other handles except the ratio 1:1.75 rectangular (Y) and the triangular (T) handles.

Torque was significantly different for each handle size and corresponded to the size; that is, larger sized handles had more torque exerted on them (Table IV-E-11).

As can be seen in Table IV-E-12, there were numerous differences between the handle shape-size configurations.

As with the analyses of the tasks discussed before, analyses of covariance were conducted using the same six covariates. The results are displayed in Tables IV-E-13, 14, and 15. The analysis of the male data indicated the four covariates: hand breadth, hand circumference,

fist circumference, and finger circumference to be significant. All
covariates were significant for the female data and all but hand breadth
were significant for the combined data of all subjects.
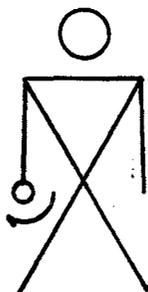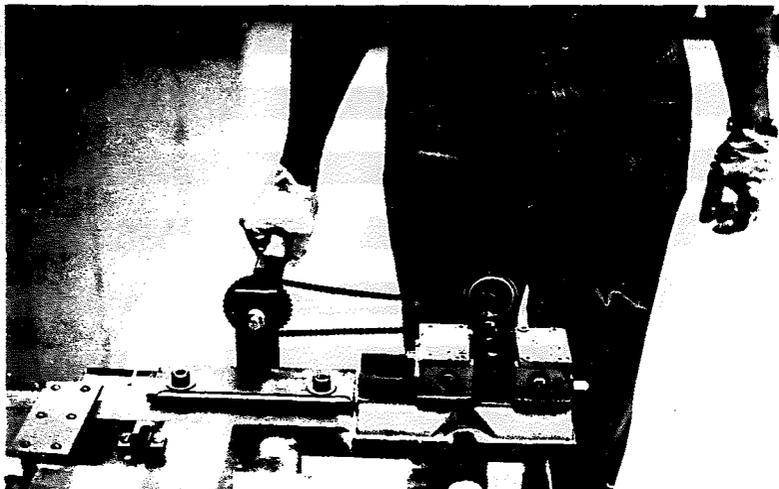
Figure IV-E-1. Wrist Extension Task

## TABLE IV-E-1

### Analysis of Variance for the Wrist Extension
### Maximum Force for Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 608.52 | 1 | 608.52 | 498.71* |
| P-Subject | R(PHS) | 10.98 | 9 | 1.22 | 369.45* |
| H-Handle Shape | PH | 41.15 | 8 | 5.14 | 71.34* |
| S-Handle Size | PS | 45.97 | 3 | 15.32 | 108.46* |
| PH | R(PHS) | 5.19 | 72 | 0.07 | 21.83* |
| PS | R(PHS) | 3.81 | 27 | 0.14 | 42.78* |
| HS | PHS | 7.01 | 24 | 0.29 | 8.66* |
| PHS | R(PHS) | 7.29 | 216 | 0.03 | 10.22* |
| R-Replicate (PHS) | | | 720 | | |

*Significant at $\alpha = 0.05$

## TABLE IV-E-2

### Results of the Tukey's Test of the Handle Shape
### for the Male Subjects Wrist Extension Data

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | X 1:1.5 | Y 1:1.75 | T | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.34 | 0.61 | 0.65 | 0.70 | 0.74 | 0.87 | 0.91 | 0.94 | 1.01 |

## TABLE IV-E-3

### Results of the Tukey's Test of the Handle Size
### for the Male Subjects Wrist Extension Data

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.45 | 0.68 | 0.87 | 1.00 |

TABLE IV-E-4

Results of the Scheffe's Test for the
Handle Shape and Size Wrist Extension
for Male Subjects

| Handle | | Mean |
|---|---|---|
| Shape | Size | Newtons |
| C | 17 | 0.2352 |
| C | 9 | 0.3090 |
| S | 7 | 0.3108 |
| C | 11 | 0.3704 |
| T | 7 | 0.4076 |
| O | 7 | 0.4161 |
| W | 7 | 0.4302 |
| C | 13 | 0.4336 |
| D | 7· | 0.4338 |
| S | 9 | 0.5462 |
| O | 9 | 0.5463 |
| X | 7 | 0.5548 |
| Y | 7 | 0.5603 |
| W | 9 | 0.6270 |
| D | 9 | 0.6638 |
| S | 11 | 0.6937 |
| O | 11 | 0.6989 |
| Z | 7 | 0.7272 |
| X | 9 | 0.7641 |
| T | 9 | 0.7971 |
| D | 11 | 0.8184 |
| D | 13 | 0.8833 |
| S | 13 | 0.8902 |
| W | 11 | 0.8942 |
| Y | 9 | 0.8974 |
| O | 13 | 0.9256 |
| X | 11 | 0.9729 |
| Z | 9 | 0.9803 |
| W | 13 | 1.0167 |
| Y | 11 | 1.0838 |
| Y | 13 | 1.0961 |
| Z | 11 | 1.1208 |
| T | 11 | 1.1373 |
| X | 13 | 1.1769 |
| Z | 13 | 1.1924 |
| T | 13 | 1.4104 |

# TABLE IV-E-5

## Analysis of Variance for the Wrist Extension
## Maximum Force for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|--------|-----------|----------------|------|-------------|---|
| Mean | P | 324.91 | 1 | 324.91 | 574.80* |
| P-Subject | R(PHS) | 5.09 | 9 | 0.57 | 242.07* |
| H-Handle Shape | PH | 16.91 | 8 | 2.11 | 57.70* |
| S-Handle Size | PS | 11.90 | 3 | 3.97 | 58.55* |
| PH | R(PHS) | 2.64 | 72 | 0.04 | 15.68* |
| PS | R(PHS) | 1.83 | 27 | 0.07 | 29.00* |
| HS | PHS | 2.34 | 24 | 0.10 | 5.22* |
| PHS | R(PHS) | 4.03 | 216 | 0.02 | 8.00* |
| R-Replicate (PHS) | | 1.68 | 720 | 0.002 | |

*Significant at $\alpha$ = 0.05

## TABLE IV-E-6

### Results of the Tukey's Test for Handle
### Shape for Wrist Extension for Female Subjects

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | X 1:1.5 | T | Y 1:1.75 | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.28 | 0.48 | 0.49 | 0.50 | 0.55 | 0.60 | 0.64 | 0.66 | 0.74 |


## TABLE IV-E-7

### Results of the Tukey's Test for Handle
### Size for Wrist Extension for Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.39 | 0.53 | 0.62 | 0.66 |

TABLE IV-E-8

Results of the Scheffe's Test for the
Handle Shape and Size Wrist Extension
Data for Female Subjects

| Handle | | Mean |
|---|---|---|
| Shape | Size | Newtons |
| C | 7 | 0.2124 |
| C | 9 | 0.2687 |
| S | 7 | 0.2969 |
| C | 11 | 0.3038 |
| C | 13 | 0.3426 |
| T | 7 | 0.3497 |
| D | 7 | 0.3567 |
| O | 7 | 0.3708 |
| W | 7 | 0.3956 |
| X | 7 | 0.4343 |
| S | 9 | 0.4360 |
| O | 9 | 0.4483 |
| O | 11 | 0.4976 |
| Y | 7 | 0.5151 |
| D | 9 | 0.5168 |
| W | 9 | 0.5171 |
| S | 11 | 0.5362 |
| D | 13 | 0.5452 |
| Z | 7 | 0.5555 |
| D | 11 | 0.5696 |
| T | 9 | 0.5765 |
| X | 9 | 0.6050 |
| Y | 9 | 0.6136 |
| W | 11 | 0.6275 |
| O | 13 | 0.6380 |
| S | 13 | 0.6431 |
| X | 13 | 0.6590 |
| W | 13 | 0.6713 |
| X | 11 | 0.7116 |
| Y | 11 | 0.7455 |
| Y | 13 | 0.7523 |
| Z | 9 | 0.7649 |
| Z | 11 | 0.7664 |
| T | 11 | 0.7875 |
| Z | 13 | 0.8561 |
| T | 13 | 0.8585 |

## TABLE IV-E-9

### Analysis of Variance for the Wrist Extension
### Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 911.37 | 1 | 911.37 | 1020.88* |
| G-Gender | P(G) | 22.06 | 1 | 22.06 | 24.72* |
| H-Handle Shape | PH(G) | 55.16 | 8 | 6.89 | 126.83* |
| S-Handle Size | PS(G) | 52.17 | 3 | 17.39 | 166.39* |
| P-Subject (G) | R(GPHS) | 16.07 | 18 | 0.89 | 316.69* |
| GH | PH(G) | 2.89 | 8 | 0.36 | 6.65* |
| GS | PS(G) | 5.70 | 3 | 1.90 | 18.18* |
| HS | PHS(G) | 5.91 | 24 | 0.33 | 12.57* |
| PH(G) | R(GPHS) | 7.83 | 144 | 0.05 | 19.29* |
| PS(G) | R(GPHS) | 5.64 | 54 | 0.10 | 37.07* |
| GHS | PHS(G) | 1.45 | 24 | 0.06 | 2.30* |
| PHS(G) | R(GPHS) | 11.33 | 432 | 0.03 | 9.30* |
| R-Replicate (GPHS) | . | 4.06 | 1440 | 0.002 | |

*Significant at $\alpha = 0.05$

## TABLE IV-E-10

### Results of the Tukey's Test for the Handle Shape Wrist Extension Data for Male and Female Subjects

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | X 1:1.5 | Y 1:1.75 | T | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.31 | 0.54 | 0.57 | 0.60 | 0.65 | 0.73 | 0.78 | 0.79 | 0.87 |

## TABLE IV-E-11

### Results of the Tukey's Test for the Handle Size Wrist Extension Data for Male and Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.42 | 0.60 | 0.74 | 0.83 |

TABLE IV-E-12

Results of the Scheffe's Test for the
Handle Shape and Size Wrist Extension
Data for Male and Female Subjects

| Handle | | Mean |
|--------|------|---------|
| Shape  | Size | Newtons |
| C | 7  | 0.2238 |
| C | 9  | 0.2888 |
| S | 7  | 0.3038 |
| C | 11 | 0.3371 |
| T | 7  | 0.3786 |
| C | 13 | 0.3881 |
| O | 7  | 0.3935 |
| D | 7  | 0.3953 |
| W | 7  | 0.4129 |
| S | 9  | 0.4911 |
| X | 7  | 0.4946 |
| O | 9  | 0.4973 |
| Y | 7  | 0.5377 |
| W | 9  | 0.5719 |
| D | 9  | 0.5904 |
| O | 11 | 0.5983 |
| S | 11 | 0.6150 |
| Z | 7  | 0.6413 |
| X | 9  | 0.6845 |
| T | 9  | 0.6868 |
| D | 11 | 0.6940 |
| D | 13 | 0.7142 |
| Y | 9  | 0.7555 |
| W | 11 | 0.7609 |
| S | 13 | 0.7666 |
| O | 13 | 0.7818 |
| X | 11 | 0.8422 |
| W | 13 | 0.8440 |
| Z | 9  | 0.8726 |
| Y | 11 | 0.9147 |
| X | 13 | 0.9180 |
| Y | 13 | 0.9242 |
| Z | 11 | 0.9436 |
| T | 11 | 0.9624 |
| Z | 13 | 1.0243 |
| T | 13 | 1.344  |

# TABLE IV-E-13

## Analysis of Covariance for Wrist
## Extension Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|------------|---------------|--------|--------|
| Mean | 0.5631 | 1 | 0.56 | 24.48* |
| H-Shape | 41.1505 | 8 | 5.14 | 223.66* |
| S-Size | 45.9731 | 3 | 15.32 | 666.32* |
| HS | 7.0150 | 24 | 0.29 | 12.71* |
| Covariates | 5.7707 | 6 | 0.96 | 41.82* |
| Grip Strength | 0.0243 | 1 | 0.02 | 1.05 |
| Hand Breadth | 1.0938 | 1 | 1.09 | 47.56* |
| Fist Circum. | 0.1256 | 1 | 0.13 | 5.46* |
| Hand " | 0.2653 | 1 | 0.27 | 11.54* |
| Forearm " | 0.0576 | 1 | 0.06 | 2.51 |
| Finger " | 0.1232 | 1 | 0.12 | 5.36*' |
| Replicate(HS) | 23.8724 | 1038 | 0.23 | |

*Significant at $\alpha = 0.05$

TABLE IV-E-14

## Analysis of Covariance for Wrist Extension
### Data for Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|--------------|-----------------|-----------|-----|
| Mean | 0.2457 | 1 | 0.25 | 23.08* |
| H-Shape | 16.9061 | 8 | 2.11 | 198.56* |
| S-Size | 11.8955 | 3 | 3.97 | 372.56* |
| HS | 2.3393 | 24 | 0.98 | 9.16* |
| Covariates | 4.2103 | 6 | 0.70 | 65.93* |
| Grip Strength | 0.1051 | 1 | 0.11 | 9.88* |
| Hand Breadth | 0.2634 | 1 | 0.26 | 24.75* |
| Fist Circum. | 0.5161 | 1 | 0.52 | 48.49* |
| Hand " | 0.2102 | 1 | 0.21 | 19.75* |
| Forearm " | 0.2692 | 1 | 0.27 | 25.30* |
| Finger " | 0.2290 | 1 | 0.23 | 21.52* |
| Replicate(HS) | 11.0475 | 1038 | 0.01 | |

Significant at $\alpha = 0.05$

# TABLE IV-E-15

## Analysis of Covariance for Wrist Extension
## Data for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 0.6097 | 1 | 0.61 | 33.7731* |
| G-Gender | 0.0121 | 1 | 0.01 | 0.6711 |
| H-Shape | 55.1624 | 8 | 6.90 | 381.9353* |
| S-Size | 52.1518 | 3 | 17.38 | 962.9084* |
| GH | 2.8923 | 8 | 0.36 | 20.0259* |
| GS | 5.7148 | 3 | 1.90 | 105.5161* |
| HS | 7.9237 | 24 | 0.33 | 18.2874* |
| GHS | 1.4326 | 24 | 0.06 | 3.3063* |
| Covariates | 7.3263 | 6 | 1.22 | 67.6349* |
| Grip Strength | 0.8070 | 1 | 0.81 | 44.7005* |
| Hand Breadth | 0.0570 | 1 | 0.06 | 3.1575 |
| Fist Circum. | 0.6586 | 1 | 0.66 | 36.4805* |
| Hand " | 0.1635 | 1 | 0.16 | 9.0564* |
| Forearm " | 0.5216 | 1 | 0.52 | 28.8936* |
| Finger " | 0.2071 | 1 | 0.21 | 11.4736* |
| Replicate(GHS) | 37.5875 | 2082 | 0.02 | |

*Significant at $\alpha = 0.05$

IV.F.  Wrist Flexion Torque

### IV.F.1  Wrist Flexion Torque Method

In the wrist flexion torque test the standing subject attempted to rotate or twist the handle, as is shown in Figure IV-F-1. This was a maximal exertion test.

### IV.F.2  Wrist Flexion Torque Results

The results of the analyses of variance on all 36 handles are contained in Tables IV-E-1, 5, and 9 for the male subjects, the female subjects and for all subjects, respectively. All terms in these models for wrist flexion were found to be significant.

The results of the Tukey tests for wrist flexion torque are almost identical to those for wrist extension. For torque exerted by male subjects, circular (C) handles were significantly lower than the others and ratio 1:1.75 (Y) and 1:2.00 (Z) rectangular handles were significantly higher, with (Z) handles significantly higher than (Y) handles (Table IV-F-2).

Torque for males was significantly different for all handle sizes and increased with size increases (Table IV-F-3).

The differences between the various handle shape-size combinations are numerous and are shown in Table IV-F-4.

In examining torque exerted by female subjects on the wrist flexion task, the circular (C) handles were significantly lower than the others. Ratio 1:1.75 (Y) and 1:2.00 (Z) rectangular handles were significantly higher than all others. These two handles were also significantly different from each other.

Torques differed significantly according to size and increased as size increased (Table IV-F-7). Also, there were numerous differences between the mean flexion torque values for the handle shape-size com-

binations, as is shown in Table IV-F-8.

With the results of all subjects combined, the wrist flexion torque using circular handles was significantly less than that for all other handles (Table IV-F-10). Ratio 1:1.75 (Y) and 1:2.00 (Z) rectangular handles had higher torque scores than all other handles. There was also a significant difference between these two handles, with (Z) being higher than (Y).

Torques for all subjects were significantly greater with increase in handle size (Table IV-F-11). As can be seen in Table IV-F-12, the Scheffe's test indicated numerous differences between the 36 different handle shape-size combinations.

Analyses of covariance are shown in Tables IV-F-13, 14, and 15 for male, female and all data on the wrist flexion task. The covariates of grip strength, forearm circumference, and finger circumference were found to be significant in the analysis of the male data. For the female data all covariates except grip strength were found to be significant. All covariates, except for fist circumference, were significant in the analysis of the combined data.
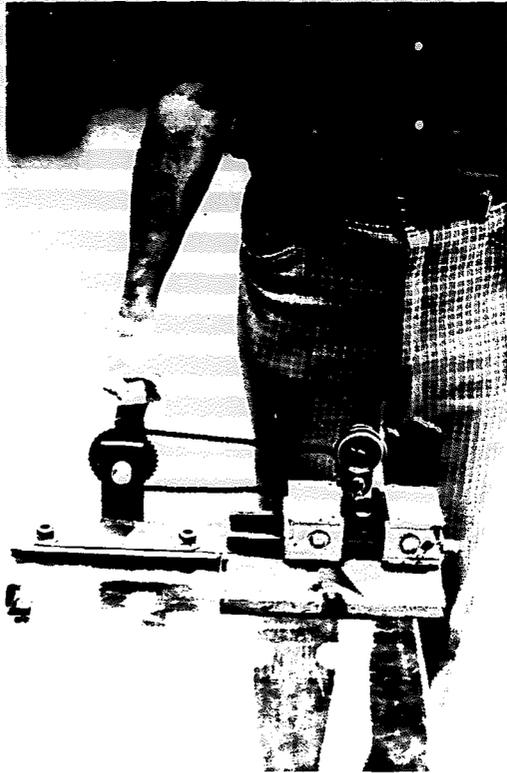
Figure IV-F-1.  Wrist Flexion Task

## TABLE IV-F-1

### Analysis of Variance for the Wrist Flexion
### Maximum Force for Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 551.73 | 1 | 551.73 | 696.36* |
| P-Subject | R(PHS) | 7.13 | 9 | 0.79 | 262.35* |
| H-Handle Shape | PH | 75.99 | 8 | 9.49 | 164.16* |
| S-Handle Size | PS | 67.73 | 3 | 22.58 | 140.44* |
| PH | R(PHS) | 4.17 | 72 | 0.06 | 19.16* |
| PS | R(PHS) | 4.34 | 27 | 0.16 | 52.23* |
| HS | PHS | 10.26 | 24 | 0.42 | 11.33* |
| PHS | R(PHS) | 8.15 | 216 | 0.04 | 12.49* |
| R-Replicate (PHS) | | 2.17 | 720 | 0.003 | |

*Significant at $\alpha = 0.05$

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TABLE IV-F-2

Results of the Tukey's Test of the
Handle Shape for the Male Subjects
Wrist Flexion Data

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | T | X 1:1.5 | Y 1:1.75 | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.23 | 0.51 | 0.54 | 0.63 | 0.65 | 0.85 | 0.85 | 1.01 | 1.16 |

TABLE IV-F-3

Results of the Tukey's Test of the
Handle Size for the Male Subjects
for the Wrist Flexion Data

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.36 | 0.62 | 0.85 | 1.03 |

## TABLE IV-F-4

### Results of the Scheffe's Test for the Handle Shape and Size Wrist Flexion Data, for Male Subjects

| Handle | | Mean |
|--------|------|---------|
| Shape | Size | Newtons |
| C | 7  | .1656 |
| C | 9  | .2013 |
| S | 7  | .2211 |
| C | 11 | .2426 |
| O | 7  | .3032 |
| T | 7  | .3140 |
| C | 13 | .3265 |
| W | 7  | .3266 |
| D | 7  | .3462 |
| O | 9  | .3889 |
| S | 9  | .4481 |
| X | 7  | .4500 |
| Y | 7  | .5160 |
| W | 9  | .5232 |
| D | 9  | .5749 |
| O | 11 | .5911 |
| S | 11 | .6051 |
| Z | 7  | .6357 |
| X | 9  | .7234 |
| D | 11 | .7341 |
| T | 9  | .7591 |
| S | 13 | .7596 |
| W | 11 | .7827 |
| Y | 9  | .8735 |
| D | 13 | .8738 |
| O | 13 | .8859 |
| X | 11 | .9773 |
| W | 13 | .9826 |
| Z | 9  | 1.0506 |
| T | 11 | 1.0911 |
| T | 13 | 1.2188 |
| X | 13 | 1.2328 |
| Y | 11 | 1.2414 |
| Z | 11 | 1.3527 |
| Y | 13 | 1.4190 |
| Z | 13 | 1.5922 |

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TABLE IV-F-5

Analysis of Variance for the Wrist Flexion
Maximum Force for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Squares | F |
|---|---|---|---|---|---|
| Mean | P | 299.77 | 1 | 299.77 | 221.19* |
| P-Subject | R(PHS) | 12.20 | 9 | 1.36 | 500.74* |
| H-Handle Shape | PH | 30.10 | 8 | 3.76 | 98.37* |
| S-Handle Size | PS | 25.14 | 3 | 8.38 | 121.84* |
| PH | R(PHS) | 2.75 | 72 | 0.04 | 14.13* |
| PS | R(PHS) | 1.86 | 27 | 0.07 | 25.41* |
| HS | PHS | 3.94 | 24 | 0.16 | 6.24* |
| PHS | R(PHS) | 5.68 | 216 | 0.03 | 9.72* |
| R-Replicate (PHS) | | 1.95 | 720 | 0.003 | |

*Significant at $\alpha$ = 0.05

TABLE IV-F-6

Results of the Tukey's Test for Handle
Shape for Wrist Flexion for Female Subjects

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | X 1:1.5 | T | Y 1:1.75 | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.20 | 0.41 | 0.42 | 0.48 | 0.53 | 0.60 | 0.61 | 0.70 | 0.81 |

TABLE IV-F-7

Results of the Tukey's Test for Handle
Size for Wrist Flextion for Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.30 | 0.48 | 0.62 | 0.71 |

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TABLE IV-F-8

Results of the Scheffe's Test for the Handle
Shape and Size Wrist Flexion Data for Female
Subjects

| Handle | | Mean |
| Shape | Size | Newtons |
|--------|------|---------|
| C | 7 | 0.14 |
| C | 9 | 0.19 |
| S | 7 | 0.20 |
| C | 11 | 0.22 |
| T | 7 | 0.26 |
| C | 13 | 0.27 |
| O | 7 | 0.27 |
| D | 7 | 0.29 |
| W | 7 | 0.32 |
| X | 7 | 0.36 |
| O | 9 | 0.36 |
| S | 9 | 0.36 |
| Y | 7 | 0.40 |
| O | 11 | 0.42 |
| W | 9 | 0.45 |
| D | 9 | 0.46 |
| S | 11 | 0.49 |
| Z | 7 | 0.49 |
| T | 9 | 0.50 |
| D | 11 | 0.57 |
| X | 9 | 0.58 |
| S | 13 | 0.58 |
| D | 13 | 0.60 |
| Y | 9 | 0.61 |
| O | 13 | 0.62 |
| W | 11 | 0.63 |
| W | 13 | 0.69 |
| X | 11 | 0.70 |
| X | 13 | 0.72 |
| Z | 9 | 0.76 |
| T | 11 | 0.77 |
| Y | 11 | 0.86 |
| T | 13 | 0.88 |
| Z | 11 | 0.90 |
| Y | 13 | 0.93 |
| Z | 13 | 1.07 |

TABLE IV-F-9

## Analysis of Variance for the Wrist Flexion
## Maximum Force for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Squares | F |
|---|---|---|---|---|---|
| Mean | P(G) | 832.43 | 1 | 832.43 | 775.24* |
| G-Gender | P(G) | 19.07 | 1 | 19.07 | 17.76* |
| H-Handle Shape | PH(G) | 100.62 | 8 | 12.58 | 261.75* |
| S-Handle Size | PS(G) | 87.59 | 3 | 29.19 | 254.40* |
| P-Subject (G) | R(GPHS) | 19.33 | 18 | 1.07 | 375.02* |
| GH | PH(G) | 5.46 | 8 | 0.68 | 14.21* |
| GS | PS(G) | 5.28 | 3 | 1.76 | 15.33* |
| HS | PHS(G) | 12.79 | 24 | 0.53 | 16.65* |
| PH(G) | R(GPHS) | 6.92 | 144 | 0.05 | 16.73* |
| PS(G) | R(GPHS) | 6.19 | 54 | 0.11 | 40.08* |
| GHS | PHS(G) | 1.39 | 24 | 0.05 | 1.82* |
| PHS(G) | R(GPHS) | 13.83 | 432 | 0.03 | 11.18* |
| R-Replicate (GPHS) | | 4.12 | 1440 | 0.002 | |

*Significant at $\alpha = 0.05$

## TABLE IV-F-10

### Results of the Tukey's Test for the Handle Shape Wrist Flexion Data for Male and Female Subjects

| Handle Shape | C | S 1:1 | O | D | W 1:1.25 | X 1:1.5 | T | Y 1:1.75 | Z 1:2 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 0.22 | 0.46 | 0.48 | 0.56 | 0.59 | 0.72 | 0.73 | 0.86 | 0.98 |

## TABLE IV-F-11

### Results of the Tukey's Test for the Handle Size Wrist Flexion Data for Male and Female Subjects

| Handle Size (cm) | 7 | 9 | 11 | 13 |
|---|---|---|---|---|
| Mean Newtons | 0.33 | 0.55 | 0.73 | 0.87 |

TABLE IV-F-12

Results of the Scheffe's Test on the Handle
Shape and Size Wrist Flexion Data for Male
and Female Subjects

| Handle | | Mean |
|---|---|---|
| Shape | Size | Newtons |
| C | 7 | 0.1504 |
| C | 9 | 0.1950 |
| S | 7 | 0.2121 |
| C | 11 | 0.2318 |
| T | 7 | 0.2879 |
| O | 7 | 0.2888 |
| C | 13 | 0.2970 |
| D | 7 | 0.3202 |
| W | 7 | 0.3245 |
| O | 9 | 0.3745 |
| X | 7 | 0.4032 |
| S | 9 | 0.4059 |
| Y | 7 | 0.4603 |
| W | 9 | 0.4871 |
| O | 11 | 0.5068 |
| D | 9 | 0.5185 |
| S | 11 | 0.5460 |
| Z | 7 | 0.5630 |
| T | 9 | 0.6318 |
| X | 9 | 0.6514 |
| D | 11 | 0.6525 |
| S | 13 | 0.6717 |
| W | 11 | 0.7088 |
| D | 13 | 0.7393 |
| Y | 9 | 0.7426 |
| O | 13 | 0.7507 |
| W | 13 | 0.8375 |
| X | 11 | 0.8384 |
| Z | 9 | 0.9062 |
| T | 11 | 0.9328 |
| X | 13 | 0.9784 |
| T | 13 | 1.0492 |
| Y | 11 | 1.0507 |
| Z | 11 | 1.1278 |
| Y | 13 | 1.1766 |
| Z | 13 | 1.3289 |

# TABLE IV-F-13

## Analysis of Covariance for Wrist Flexion
## Data for Male Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|----------------|--------------------|-------------|---|
| Mean | 0.5909 | 1 | 0.59 | 25.65* |
| H-Shape | 75.9844 | 8 | 9.50 | 412.30* |
| S-Size | 67.7292 | 3 | 22.58 | 980.03* |
| HS | 10.2567 | 24 | 0.43 | 18.55* |
| Covariates | 2.0324 | 6 | 0.34 | 14.70* |
| Grip Strength | 0.8487 | 1 | 0.85 | 36.84* |
| Hand Breadth | 0.0732 | 1 | 0.73 | 3.18 |
| Fist Circum. | 0.175 | 1 | 0.18 | 0.76 |
| Hand " | 0.0066 | 1 | 0.01 | 0.28 |
| Forearm " | 0.2211 | 1 | 0.22 | 9.60* |
| Finger " | 0.2087 | 1 | 0.21 | 9.06* |
| Replicate(HS) | 23.9119 | 1038 | 0.23 | |

*Significant at $\alpha$ = 0.05

TABLE IV-F-14

## Analysis of Covariance for Wrist Flextion
## Data for Female Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|--------|------|----|------|------|
| Mean | 1.0750 | 1 | 1.08 | 75.97* |
| H-Shape | 30.0972 | 8 | 3.76 | 265.86* |
| S-Size | 25.1354 | 3 | 8.38 | 592.09* |
| HS | 3.9366 | 24 | 0.16 | 11.59* |
| Covariates | 9.7395 | 6 | 1.62 | 114.71* |
| Grip Strength | 0.0004 | 1 | 0.00 | 0.03 |
| Hand Breadth | 0.3413 | 1 | 0.34 | 24.12* |
| Fist Circum. | 0.3939 | 1 | 0.39 | 27.84* |
| Hand    " | 2.4032 | 1 | 2.40 | 169.83* |
| Forearm " | 1.7768 | 1 | 1.78 | 125.56* |
| Finger  " | 3.9366 | 1 | 3.94 | 278.19* |
| Replicate(HS) | 14.6883 | 1038 | 0.01 | |

*Significant at $\alpha$ = 0.05

TABLE IV-F-15

Analysis of Covariance for Wrist Flexion
Data for All Subjects

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F |
|---|---|---|---|---|
| Mean | 0.0208 | 1 | 0.02 | 0.9918 |
| G-Gender | 0.9216 | 1 | 0.92 | 43.9787* |
| H-Shape | 100.6196 | 8 | 12.58 | 600.2253* |
| S-Size | 87.5686 | 3 | 29.19 | 1392.9932* |
| GH | 5.4280 | 8 | 0.68 | 32.3796* |
| GS | 5.2603 | 3 | 1.75 | 83.6772* |
| HS | 12.8120 | 24 | 0.53 | 25.4758* |
| GHS | 1.4101 | 24 | 0.56 | 2.8039* |
| Covariates | 6.7201 | 6 | 1.12 | 53.4499* |
| Grip Strength | 0.7245 | 1 | 0.72 | 34.5740* |
| Hand Breadth | 0.8110 | 1 | 0.81 | 38.7018* |
| First Circum. | 0.0714 | 1 | 0.71 | 3.4097 |
| Hand " | 0.4597 | 1 | 0.46 | 21.9389* |
| Forearm " | 2.3051 | 1 | 2.31 | 110.0062* |
| Finger " | 1.2950 | 1 | 1.30 | 61.8023* |
| Replicate(GHS) | 43.6273 | 2082 | 0.02 | |

*Significant at $\alpha = 0.05$

IV.G. Conclusions

Conclusions for Phase 1 will be covered for the thrust tests, the orthogonal tests, and the torque tests separately.

IV.G.1 Thrust Test Conclusions

As an overall conclusion it can be said that for both thrust tests the handle shape and the handle size affect the force that can be exerted. Also, in two cases these factors interact so that a shape or size for a handle cannot always be selected independently of one another.

In examining handle shape force means, one fact is apparent - circular (C) handles are significantly inferior to one or more of the other shapes and had the least force exerted on them. In contrast, for most of the analyses conducted, the triangular (T) handles were significantly better than the circular (C) handles. Also, square (S) handles tend to have low forces exerted on them, while the 1:2.0 (Z) handles tend to have high forces exerted on them. Between the two handle shapes associated with low forces and the two associated with high forces are the various rectangular and modified circular handles.

It should be noted that the extremes of force are associated with the extremes in handle shapes. The low force handles, the circular (C) and square (S), are the most uniform and the high force handles are the extreme rectangular 1:2.0 (Z) and the unorthodox triangular (T) handles.

In examining handle size it is apparent that, to a point, thrust forces will increase with an increase in size. Quite often in the analyses of both tests the 7 and 9 cm handles differed from each other and both differed from the 11 and 13 cm handles (which were not significantly different from each other). This may indicate that peak thrust

forces can be exerted on handles in the 11 to 13 cm (and maybe a little beyond) range. An indication that females' thrust force may be highest at handle circumferences a little smaller is shown in Tables IV-A-6 and IV-B-6. In these tables there is no significant difference between the 9, 11 and 13 cm handles. In one of these tables the average force values are very close, and in the other, the 9 cm is higher (not significantly, than the other two.

In summary, triangular (T) handles and rectangular ratio 1:2.00 (Z) handles should be selected to maximize the thrust forces. Circular (C) and square (S) handles should be avoided when large thrust forces are to be exerted. For females, handles 9 cm or larger in perimeter (probably in the range of 9 to 11 cm) are best for thrust forces. For males, handles in the 11 and 13 cm range appear to maximize the thrust forces possible. Where interactions between shape and size were significant, the data also indicated generally that the triangular (T) and rectangular 1:2.0 ratio (Z) handles, in the 11 to 13 cm range for males and 9-11 cm range for females, were associated with higher thrust forces.

## IV.G.2  Orthogonal Force Tests Conclusions

In the conduct of the orthogonal force tests the subject exerted a
horizontal force on a vertical handle held stationary at the top (see
figures IV-C-1 and IV-D-1). Although the wrist was maintained in the
neutral position, applying force on the push task caused a moment about
the wrist which attempted to force the wrist into radial deviation.  The
pull task tended to force just the opposite - ulnar deviation.  In
opposing radial deviation during the push task, the fingers (primarily
the smaller fingers) exert a force to prevent the handle from rotating
about the crotch between the thumb and forefinger.  This crotch with its
fleshy padding acts as a fulcrum in a simple class 1 lever system.  In
opposing ulnar deviation in the pull task, the handle rests against the
hypothenar eminence (fleshy pad on the medral side of the palm) and the
fingers (primarily the index and middle fingers) apply a force.  In this
case the hypothenar eminence acts as a fulcrum in a simple class 3 lever
system.  These differences in classes of levers, in fulcrums, and in
fingers exerting force make it apparent that very different handles may
be preferred for the push task as opposed to the pull task.  Upon examina-
tion of the data and analyses, this is found to be true.

For the orthogonal push task the circular (C) handles had the highest
forces exerted on them.  The circular with two flat sides (O) was next
and was close in forces to the "C" handles.  Forces exerted on triangular
and rectangular ratio 1:2.0 (Z) handles were generally the smallest.  The
difference between the "Z" handles and the "C" handles was significant
in every case.

In examining the progression of average forces for each handle shape
in tables IV-C-2, 5 and 7, it becomes apparent that the major determinant
of push force is the proportion of the perimeter of the handle which is

on a narrow side of the handle. As an example, if the rectangular handles with ratios 1:1.25 (W) and 1:2.0 (Z) are compared, the percent of the perimeter on a narrow side is approximately 22.22% for "W" and 16.67% for "Z" handles. This means that the "W" handle has 33.33% more of its perimeter resting on the fulcrum between the thumb and forefinger. It does not seem surprising then that for both sexes and for all subjects' data combined, the force exerted with "W" handles for the orthogonal push was greater (not significantly) than for "Z" handles.

The triangular handles performed poorly on the push task because, no matter how they are oriented, there is always a small bearing surface pointed at the fulcrum between the thumb and forefinger, thereby creating a pressure point. A pressure point from exerting a force on a handle can cause pain and would limit the force exerted.

On the orthogonal pull task the handle shape played a significant role in the force exerted. The circular handles were associated with low forces, while the rectangular ratio 1:1.50 (X) and triangular handles were associated with high forces. The "X" and "C" handles were significantly different from each other.

The triangular (T) handle was near the top on this, the pull test, and was the bottom handle on the push test. A possible reason it did well on the pull test might be the positioning of the triangular (T) handle in the hand. When performing an orthogonal pull task a flat side of the triangular handle is placed against the hypothenar eminence of the palm and fingers naturally wrap around and form to the opposite apex. This produces a good frictional contact of a large area of the palm with a flat side of the handle and a comfortable surface around which the fingers wrap and exert force.

In examining the results of the analyses of the effects of handle size on the forces exerted in the orthogonal push and pull, it becomes apparent that the largest handles (13 cm) were always associated with the lowest forces. On the other hand, the two smaller handle sizes (7 and 9 cm) were associated with the high forces.

On the pull task the interaction of shape and size was significant. This indicates that, for orthogonal pull, handle shape and handle size cannot be selected independently.

Of note is the fact that the orthogonal push forces were significantly greater than the orthogonal pull forces. This is primarily due to the advantage of a class 1 lever system over a class 3 one. Also contributing may have been the greater inherent stability of the handle when pushing than when pulling. When pulling the slippery handle resting on the hypothenar eminence of the palm, which acted as the fulcrum, would tend to slip off. This was not the case for the stable crotch fulcum of the push task.

IV.G. 3 Torque Tests Conclusions

The results of all analyses of the torque tests are in almost complete agreement. Shape of the handle was significant in all cases. When the mean torque values are arranged in ascending order, the sequence is almost identical for all groups for extension and flexion. The triangular handle is the only one to change relative positions.

If the maximum distance from the center of the handle cross section to the farthest point on the handle perimeter is examined, it gives a strong indication of the cause of the consistent sequence. These distances are closely related to the maximum moment arm available when using these handles to exert torque. Table IV-G-1 gives the maximum moment arm for each handle shape relative to the maximum moment arm of the circular handle. With the exception of the square (S) handle, this hierarchy corresponds to that found experimentally. The T and Y handles have the same relative moment arm, which explains why 'T' and 'Y' handles vie for second place in the experimentally derived hierarchies. The only handle shape that really differs in position between the relative moment arm hierarchy and the experimentally derived hierarchies is the square (S) handle. The reason for this is unknown.

The variable of handle size was significant in all analyses of torque data. The effect of handle size on torque is proportional to the size. This means that more torque can be exerted using the larger handles of this study. There is a limit to this relationship as other researchers have found (Ayoub and Lo Presti; 1971, Pheasant and O'Neill, 1975); however, the handle sizes used in this research were not large enough to show this. This was by design as handles larger than those tested were not considered practical as knife handles.

In the analyses conducted on torque, the interaction of handle shape and handle size was significant. This indicates that, in the selection of handles for the application of torque, shape and size cannot be selected independently.

In summary, results on the torque tests were extremely consistent and related to the relative moment arm of the handle shapes. In the range of sizes tested more torque could be exerted using the larger handles. Due to the significance of the handle shape-size interaction terms, care should be taken when selecting a shape-size combination for a handle.

## TABLE IV-G-1

Handle Shapes with Relative Moment Arms –
Maximum Distance from the Handle Center to
a Point on the Handle Surface

| Handle Shape | Relative Moment Arm |
|:---:|:---:|
| C | 1.000 |
| O | 1.029 |
| D | 1.042 |
| S | 1.079 |
| W | 1.090 |
| X | 1.115 |
| T | 1.145 |
| Y | 1.145 |
| Z | 1.176 |

## V.  METHOD, RESULTS AND CONCLUSIONS - PHASE 2

Phase 2 consisted of two fatigue tests.  The first was a static load fatigue test and the second was a static load with random impulses fatigue test.  The handles tested and the method of selecting them is presented first, followed by method, and then results and conclusions.  The results and conclusions for Phase 2 are presented separately for the two tests conducted; however, the two tests are so similar that the methods are almost identical and will be presented together.

### V.A.  A Handle Selection

The handles selected for use in phase 2 were from among the best of the handles of phase 1.  Since the fatigue test to be used required that the subject exert a constant thrust push type force, it was determined that those handles having high average force scores, and therefore high marks on this test, would be the most likely to include.  However, the forces exerted on other tasks, in particular the thrust pull task, were taken into account in the selection process.  The eleven handles selected are listed in Table V-A-1 with their respective ranking for force by all subjects, male subjects and female subjects on both thrust tasks.  The bottom line of the table is the lowest  or work rank on that list of the handles selected.

### V.B.  Method

For the fatigue tests the subject was seated, as is shown in Figure V-B-1.  The subject held a handle with slippery film against a constant force until fatigue.  The constant load was achieved by attaching one end of the handle to a cable which ran horizontally to a ballbearing pulley and then vertically.  A weight was attached to the end of the vertical cable, as is depicted in Figure V-1.  The subject's arm was straight at

TABLE V-A-1

Handles Used in Phase 2 Along With Their
Respective Rankings on the Thrust Tasks
for All Subjects, Male Subjects, and Female
Subjects

|  | THRUST PUSH | | | THRUST PULL | | |
|---|---|---|---|---|---|---|
|  | A | M | F | A | M | F |
| 09 | 12 | 20 | 3 | 20 | 21 | 12 |
| 011 | 11 | 17 | 4 | 13 | 19 | 6 |
| 013 | 5 | 5 | 12 | 3 | 5 | 3 |
| T9 | 3 | 2 | 13 | 10 | 16 | 5 |
| T11 | 6 | 4 | 15 | 5 | 2 | 10 |
| T13 | 2 | 3 | 6 | 4 | 1 | 11 |
| W11 | 4 | 10 | 1 | 6 | 4 | 9 |
| X13 | 1 | 1 | 8 | 1 | 3 | 2 |
| Y11 | 13 | 14 | 7 | 7 | 10 | 4 |
| Y13 | 10 | 7 | 14 | 9 | 7 | 13 |
| Z13 | 8 | 11 | 5 | 2 | 9 | 1 |
| Last Rank | 15 | 20 | 15 | 20 | 21 | 13 |
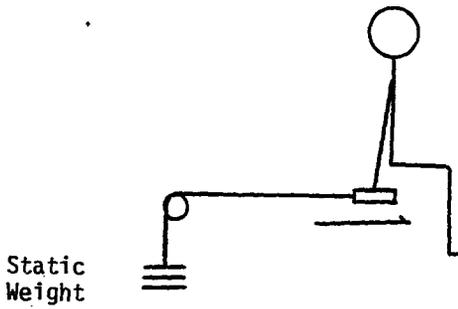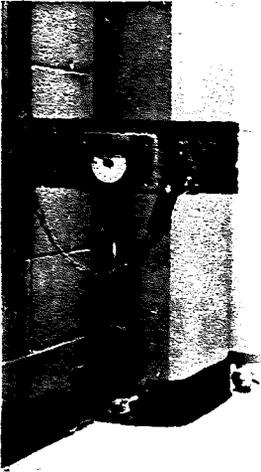
Static
Weight

Figure V-B-1.   Static Fatigue Test

the elbow and he/she maintained the handle in a constant position relative to the chair and body by pushing forward. This application of force by the subject was the same as that of the thrust push test of Phase 1. Subjects were instructed to maintain this force for as long as possible and to be consistent in their effort from trial to trial.

In the static test the subject was required to maintain a force of 35% of his/her maximum on a cylindrical handle of 10 cm circumference (3.18 cm diameter). For the static test the arm was braced just above the elbow so that the test would not be terminated because of fatigue of muscles other than the grasping muscles (See Figure V-B-2). All static tests were conducted using the dominant hand.

The impulse test was different in several particulars (Figure V-B-3). The force was the same but at random intervals (approximately every 15 seconds). There was an impulse force in addition to the constant force. This impulse was created by dropping a 385 gram weight a distance of 15 cm onto the weights responsible for the constant force (See Figure V-B-4). Between impulses the 385 gram weight was held suspended so that it did not add to the constant weight. The dropping weight was silent and therefore was not anticipated by the subjects. Because of the impulse's tendency to pull the hand and arm slightly backward, the brace just above the elbow used in the static test was not used. It was felt that the brace interfered with the test and might cause pain in the elbow joint. All impulse tests were conducted using the subject's non-dominant hand.

The experimental design for each fatigue test was a two factor analysis of variance with blocking on subjects. The two factors were handle with eleven levels and gender with two levels. Twenty subjects (10 male and 10 female) were tested on both fatigue tests.

Figure V-B-2.   Arm Rest for Static Fatigue Test

Impulse
Weight

Pulley

Static
Weight
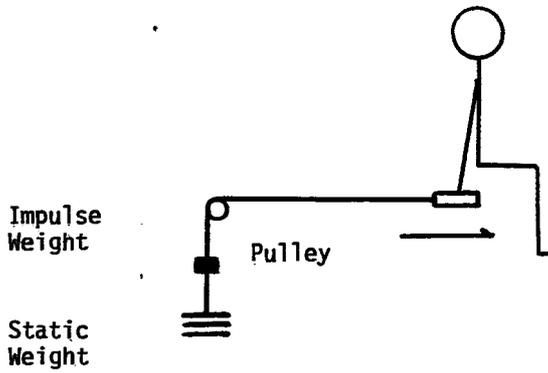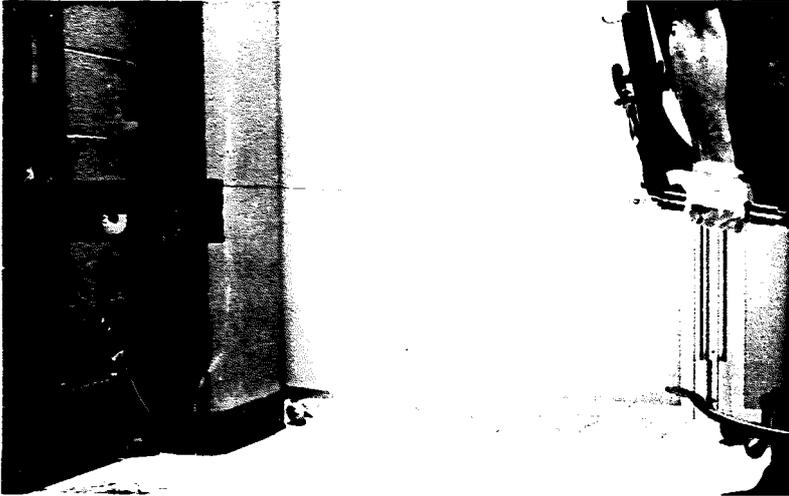
Figure V-B-3.   Fatigue with Impulse Test
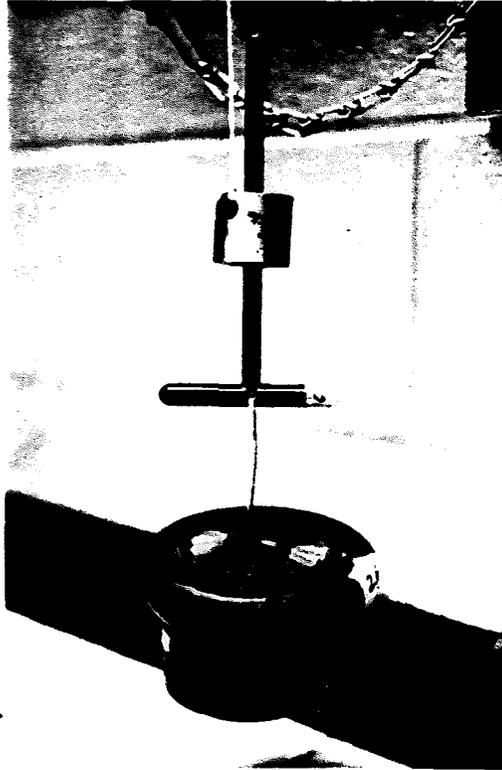
Figure V-B-4.  Suspended Constant Weight and
                Impulse Weight

The handles selected for the fatigue tests were selected based primarily upon the results of the thrust push test of phase 1. As was discussed in some detail in the conclusions to phase 1 and part A of this section of the report, these 11 handles were among the best for the males, for the females, and/or for all subjects. Each subject performed both fatigue tests on all 11 handles.

V.C.  Static Fatigue Test

V.C.1  Static Fatigue Test Results

The results of the analyses of variance for the time to fatigue as determined by the subjects' inability to continue are presented for male, female, and all subjects in tables V-C-1, 2, and 3, respectively. None of the factors tested was shown to be significant in any of these three analyses.

V.C.2  Static Fatigue  Test Conclusions

From the analyses of variance for male, female and all subjects the only conclusion that can be drawn is that for the 11 handles selected as best from phase 1, there is no significant difference between them. This conclusion is valid for fatigue in maintaining a thrust push type force until the subject can no longer continue.

V.D.  Impulse Fatigue Test

V.D.1  Impulse Fatigue Test Results

The results of the analyses of variance for the time to fatigue as was determined by the subjects' inability to continue are presented in tables V-D-1, 2, and 3 for male, female and all subjects, respectively. None of the factors tested was determined to significantly affect the time to fatigue in any of these three analyses.

V.D.2  Impulse Fatigue Test Conclusions

From the analyses of variance for male, female and all subjects

## TABLE V-C-1

Analysis of Variance on the Time to Fatigue
for Male Subjects in the Satre Test as Deter-
mined by the Subject's Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Squares | F |
|---|---|---|---|---|---|
| Mean | P | 16421227. | 1 | 16421227. | 16.93 |
| P-Subject | | 8728685. | 9 | 969854. | |
| H-Handle Shape | PH | 269601. | 10 | 26960. | 0.61 |
| PH | | 3958318. | 90 | 43981. | |

TABLE V-C-2

Analysis of Variance on the Time to
Fatigue for Female Subjects in the
Static Test as Determined by the
Subject's Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Squares | F |
|---|---|---|---|---|---|
| Mean | P | 5792351. | 1 | 5792350.6 | 66.21 |
| P-Subject | | 787329. | 9 | 87480.9 | |
| H-Handle Shape | PH⁻ | 86735. | 10 | 8673.5 | 1.52 |
| PH | | 515140. | 90 | 5723.8 | |

TABLE V-C-3

Analysis of Variance on the Time to
Fatigue for All Subjects in the Static
Test as Determined by the Subject's
Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Squares | F |
|---|---|---|---|---|---|
| Mean | P(G) | 20859609. | 1 | 20859609. | 39.46 |
| G-Gender | P(G) | 1353969. | 1 | 1353969. | 2.56 |
| H-Handle Shape | PH(G) | 139419. | 10 | 13942. | 0.56 |
| P-Subject (G) | | 9516013. | 18 | 528667. | |
| GH | PH(G) | 216917. | 10 | 21692. | 0.87 |
| PH | | 4473458. | 180 | 24853. | |

TABLE V-D-1

Analysis of Variance on the Time to
Fatigue for Male Subjects in the
Impulse Test as Determined by the
Subject's Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 5747918. | 1 | 5747918.4 | 33.94 |
| P-Subject | | 1524330. | 9 | 169370.0 | |
| H-Handle Shape | PH | 89193. | 10 | 8919.3 | 1.36 |
| PH | | 590407. | 90 | 6560.1 | |

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TABLE V-D-2

Analysis of Variance on the Time to
Fatigue for Male Subjects in the
Impulse Test as Determined by the
Subject's Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 3043456. | 1 | 3043456.4 | 63.70 |
| P-Subject | | 430002. | 9 | 47778.0 | |
| H-Handle Shape | PH | 39906. | 10 | 3990.6 | 1.28 |
| PH | | 281012. | 90 | 3122.4 | |

## TABLE V-D-3

### Analysis of Variance on the Time to
### Fatigue for All Subjects in the
### Impulse Test as Determined by the
### Subject's Inability to Continue

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 8578215. | 1 | 8578215.3 | 79.01 |
| G-Gender | P(G) | 213160. | 1 | 213159.6 | 1.96 |
| H - Shape | PH(G) | 84090. | 10 | 8409.0 | 1.74 |
| P(G) - Subject | | 1954332. | 18 | 108574.0 | |
| GH | PH(G) | 45010. | 10 | 4501.0 | 0.93 |
| PH(G) | | 871420. | 180′ | 4841.2 | |

the only conclusion that can be drawn is that for the handles tested, the impulse fatigue test detected no significant difference among these.

## V.E.   Fatigue Test Conclusions

From the fatigue tests it can be concluded that the eleven handles were close enough in good grasping characteristics that there is no appreciable difference when applying a thrust push force.  This would seem to indicate that for knife handles any of the eleven would exhibit equal fatigue-inducing characteristics when jabbing the knife point first into the meat.  This does not, however, tell how these handles would fare in fatigue tests applying forces other than push thrust.

In this phase of the study the parameters affecting the functions of guards on knife handles were examined. Methods of guarding currently in use were examined. Conclusions were made as to what guard configurations would be accepted by workers and management. Based upon this, guards with various parameters were tested on one handle.

The function of a guard is to prevent the hand holding the knife from slipping forward on to the cutting edge. This type of accident is not uncommon in meat packing and can result in severe injury. It normally occurs when the worker is in the act of jabbing the knife in, point first, and the tip hits a bone or the table. The unexpectedness and abruptness of this, along with the possibility of fatigue and a slippery handle, increase the likelihood that the worker's hand will slip.

There are four basic methods of guarding the knife hand from slipping over the cutting edge. Three of these place a barrier or enlargement between the hand and the cutting edge. The fourth attaches or ties part of the hand to the rear (away from the blade) of the handle. In this fourth method, generally, the little finger is placed in a nylon or other durable material loop which is attached to a swivel on the rear end of the handle. With the little finger in the loop, the hand cannot slip over the cutting edge. Although this does keep the hand from sliding over the front of the handle and onto the edge, it does have some drawbacks. First, without removing the little finger from the loop, the knife can be used in only two of the four positions described in the introduction of this report (Figure I-1). Second, the loop tends to irritate the little finger, cause blisters and callouses,

and may even lead to functional problems.

The first of the barrier-type of guards in use is the simple tang. This is a protrusion (usually an integral part of the wood or plastic handle) downward from the handle, as in Figure VI-A-1. This is the most common type of guard and is present to some extent on every knife used in quantity by meatpackers. The second barrier-type guard adds a side plate to the handle already having a tang guard. Generally, this protrudes about 1/4 to 3/8 of an inch at a right angle from one side of the handle. The third barrier type of guard is sometimes called the bale guard and consists of a heavy wire loop placed on the handle, as can be seen in Figure VI-A-2.

The tang guard is the most prevalent. The side plate guard can be effective but many workers find it an irritant and complain that any-thing that protrudes from the side of the handle can interfere with cutting close to the bone or hide in some operations. The bale is clumsy and interferes with some cutting operations and with rapid changing of knife positions in the hand.

In talking with meatpacking workers and trial use of handles with various guards by these same workers, it was concluded that the guard-type most likely to be accepted and used would be some sort of a tang guard. Since virtually all knives have tang guards on them and there are still injuries from slipping over the cutting edge, it has to be concluded that at least some of the tang guards on knives currently in use are inadequate. Therefore, the decision was made to examine the pertinent parameters of tang guards.

The two parameters of tang guards evaluated were the effective height and the radius of curvature of the transition from handle to tang (see Appendix C). Effective height is the vertical height of the
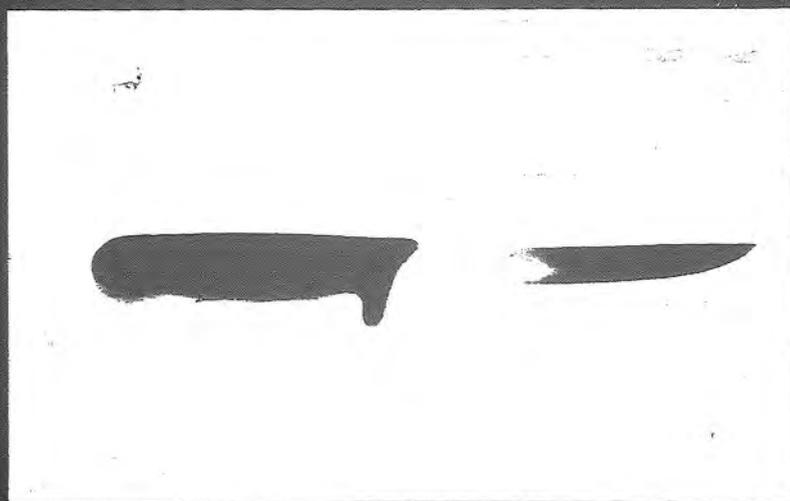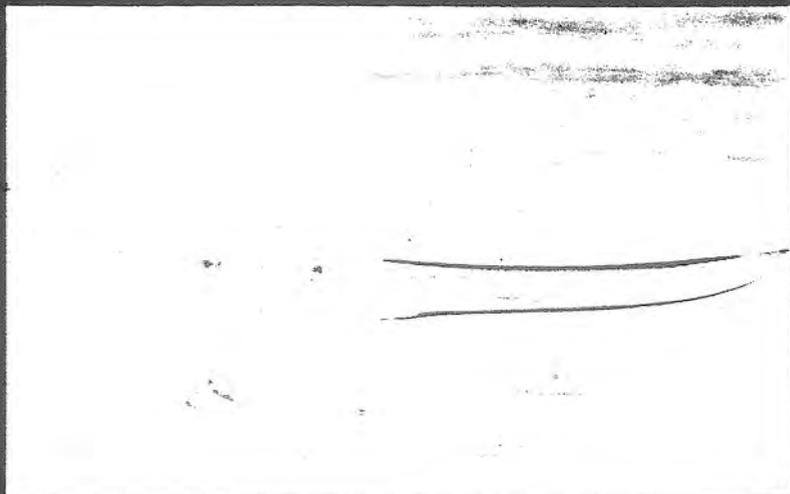
Figure VI-A-1.  Handles with tang barrier type guards
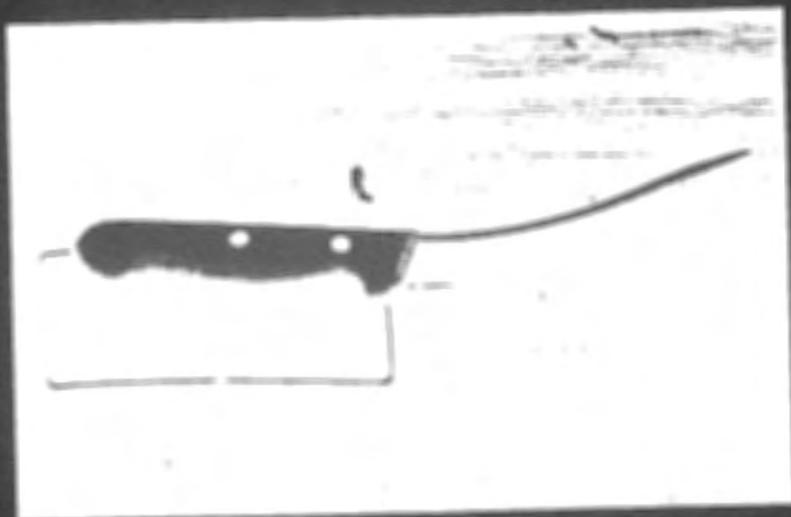
Figure VI-A-2. Handle with bale barrier type guard

guard above the handle. This is measured from the low point of the area on the handle where the index finger will be when the knife is held in the slicing position. This height does not include that part of the tang guard which begins to curve or recurve toward the blade. The four heights were 0.508, 1.016, 1.524 and 2.032 cm. The three radii of curvature were 0.533, 0.8 and 1.067. All combinations of the four heights and the three radii of curvature were tested.

The height dimensions were based upon a small sample estimate of the diameter of the 2nd phalange of the forefinger for males. This diameter was approximately 2.032 cm. Males were used because it was believed that if a guard was adequate for the larger male finger, it would be even better for the smaller female finger. The heights used were 25, 50, 75, and 100% of the forefinger diameter. The smallest height is greater than any of the handles on the Chicago knives of Table I-1 have. The largest height is greater than any of the handles of Table I-1 have. The radii used were selected to span the range shown to be on present handles in Table I-1.

Each guard was tested on nine male and nine female subjects. The test consisted in having each subject put on a plastic glove, grasp the slippery handle with a guard on it and push as hard as possible. This is actually a repeat of the thrust push test, only this time one handle was used with various guards and the subject used the guard to push against.

Three anthropometric measurements were made and recorded for the subjects participating in phase three of this project. These measurements were all taken of the forefinger and included the thickness of the first

phalanges, the second phalanges and the first-second phalangeal joint - all of the index finger (see Appendix D for diagrams and definitions of all anthropometric measurements and Appendix I for the actual data for phase 3).

- The experimental design was a three factor one with blocking on subjects. The factors were the guard height, the radius of curvature of the transition from the handle to the guard, and gender. Subjects were nested under gender. In addition to the analysis of variance of this model, analyses were conducted using the data of the males and females separately.

VI.B. Results

The results of the analyses of variance on the maximum thrust push force with guards on the handle are shown in tables VI-B-1, 2 and 3 for the male subjects, female subjects and all subjects, respectively. The radii of transition were found to not significantly affect the maximum force exerted. The height of the guards did affect the maximum force exerted for males, females and for all subjects.

The mean forces for the four heights are shown graphically in figure VI-B-1 for males, females and all subjects. In examining the means for male subjects using the Tukey's test (Table VI-B-4) the shortest (0.508 cm) was significantly less than the other heights. The next shortest (1.016 cm) was significantly less than the two greater heights. The two largest heights (1.524 and 2.032 cm) were not significantly different from each other in maximum force exerted by male subjects.

For female subjects the forces exerted when using the smallest

## TABLE VI-B-1

### Analysis of Variance of the Maximum
### Force with Guards for Male Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 7658065.5 | 1 | 7653065.512 | 354.44* |
| P-Subject | T(PRH) | 172850.3 | 8 | 21606.293 | 330.70* |
| R-Radius | PR | 3096.6 | 2 | 1548.299 | 3.31 |
| H-Height | PH | 210388.4 | 3 | 70129.478 | 53.65* |
| PR | T(PRH) | 7481.2 | 16 | 467.574 | 7.16* |
| PH | T(PRH) | 31373.2 | 24 | 1307.216 | 20.01* |
| RH | PRH | 1085.8 | 6 | 180.973 | 0.54 |
| PRH | T(PRH) | 16013.1 | 48 | 333.607 | 5.11* |
| T(PRH) | | 14112.2 | 216 | 65.334 | |

*Significant at $\alpha = 0.05$

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## TABLE VI-B-2

### Analysis of Variance of the Maximum
### Force with Guards for Female Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P | 2948272.305 | 1 | 2948272.31 | 157.87* |
| P-Subject | T(PRH) | 149403.828 | 8 | 18676.48 | 418.04* |
| R-Radius | PR | 20.886 | 2 | 10.44 | 0.10 |
| H-Height | PH | 16798.835 | 3 | 5599.61 | 12.20* |
| PR | T(PRH) | 1674.970 | 16 | 104.69 | 2.34* |
| PH | T(PRH) | 11013.697 | 24 | 458.90 | 10.27* |
| RH | PRH | 638.970 | 6 | 106.50 | 0.55 |
| PRH | T(PRH) | 9229.268 | 48 | 192.277 | 4.30* |
| T-Replicate(PRH) | | 9649.509 | 216 | 44.67 | |

*Significant at $\alpha = 0.05$

135

TABLE VI-B-3

Analysis of Variance of the
Maximum Force with Guards
for All Subjects

| Source | Error Term | Sum of Squares | D.F. | Mean Square | F |
|---|---|---|---|---|---|
| Mean | P(G) | 10054806.78 | 1 | 0.10055D 08 | 499.22* |
| G-Gender | P(G) | 551531.04 | 1 | 0.55153D 06 | 27.38* |
| R-Radius | PR(G) | 1694.50 | 2 | 847.25 | 2.96 |
| H-Height | PH(G) | 172891.62 | 3 | 57631. | 65.26* |
| P-Subject(G) | T(GPRH) | 322254.17 | 16 | 20141. | 366.17* |
| GR | PR(G) | 1422.98 | 2 | 711.49 | 2.49 |
| GH | PH(G) | 54295.65 | 3 | 18099. | 20.50* |
| RH | PRH(G) | 787.75 | 6 | 131.29 | 0.50 |
| PR(G) | T(GPRH) | 9156.15 | 32 | 286.13 | 5.20* |
| PH(G) | T(GPRH) | 42386.89 | 48 | 383.06 | 16.05* |
| GRH | PRH(G) | 937.05 | 6 | 156.18 | 0.59 |
| PRH(G) | PRH(G) | 25242.38 | 96 | 262.94 | 4.78* |
| T-Replicate(GPRH) | | 23761.71 | 432 | 55.004 | |

*Significant at $\alpha = 0.05$

FIG.VI-B-1 AVERAGE MAXIMUM FORCE
WITH DIFFERENT GUARD HEIGHT

⊙ : ALL SUBJECTS
△ : MALE
✳ : FEMALE
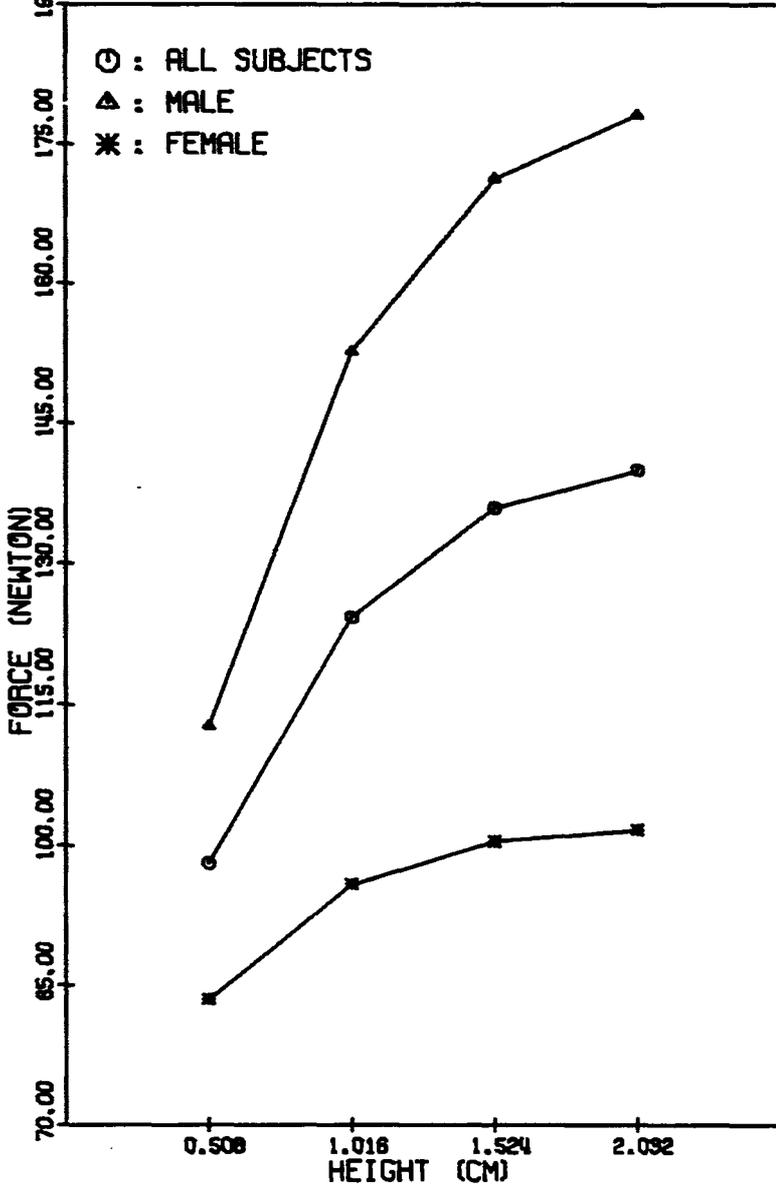
## TABLE VI-B-4

### Results of the Tukey's Test of Guard Height for Male Subjects

| Guard Height (cm) | 0.508 | 1.016 | 1.524 | 2.032 |
|---|---|---|---|---|
| Mean (Newtons) | 112.67 | 152.72 | 171.35 | 178.22 |

## TABLE VI-B-5

### Results of the Tukey's Test of Guard Height for Female Subjects

| Guard Height (cm) | 0.508 | 1.016 | 1.524 | 2.032 |
|---|---|---|---|---|
| Mean (Newtons) | 83.50 | 95.87 | 100.50 | 101.70 |

guard height (Figure VI-B-1 and Table VI-B-5) were significantly less than for the other three. The three larger heights were not significantly different from each other.

The Tukey's test for differences between the guard height for all subjects (Figure VI-B-1 and Table VI-B-6) is the same as that of the males. The highest two were not different from each other but were different from the lowest two (which were different from each other).

VI.C  Conclusions

There are several conclusions that can be made from the results of the analyses of the phase 3 (guard evaluation) data. First, the radius of transition (in the range of radii tested) had no effect on the maximum force exerted. Second, for female subjects there is minimal improvement in the force exerted when the guard height was over 1.016 cm. Third, there is minimum improvement in the force exerted by male subjects when the guard height is over 1.524 cm. The same is true for all subjects. If tang guards were made high enough for male workers to maximize thrust push, they would be more than adequate for female subjects. Therefore, a guard height adequate for male subjects will be adequate for female subjects.

The basic overall conclusion from this is that guards 1.016 cm or less may be inadequate (depending on gender) and guards 1.524 cm or more should be adequate for all workers. Inherent in these conclusions is the assumption that under the conditions of a slippery handle, the minimum guard height at which maximum force can be exerted is also the minimum height at which a tang guard becomes effective in preventing the hand from sliding off of the handle.

The fact that this testing has determined a 1.016 cm high guard may

TABLE VI-B-6

Results of the Tukey's Test of Guard
Height for All Subjects

| Guard Height (cm) | 0.508 | 1.016 | 1.524 | 2.032 |
|---|---|---|---|---|
| Mean (Newtons) | 98.08 | 124.30 | 135.93 | 139.96 |

be inadequate should be related to the heights of present meat packing knives featured in Figure I-1. Only one of these has a total guard height (higher than the effective height) over 1.016 cm. It would appear that present tang guards are, therefore, inadequate.

# VII. SUMMARY AND CONCLUSIONS

Although this study examined possible handle configurations for meat-packing knives, the results have a much broader application to all handles and tools. The study was divided into three phases. Phase 1 examined the maximum force capabilities using all combinations of nine handle shapes and four handle sizes on six tests. Phase 2 used eleven handles, selected from phase 1 because of their superior performance, in two fatigure tests. Phase 3 measured the maximum force capabilities for a handle with twelve different guards. The guards tested consisted of all combinations of tang guards having one of four heights and one of three radii of transition from the handle to the guard.

All tests were conducted under the condition of a slippery film. Subjects wore a disposable plastic glove which was coated with a slippery film. The handles were made from plastic and each had a smooth surface. This smooth, plastic handle, a plastic glove, and a slippery film between them, made the hand-handle coupling slippery. This slippery film method was used to accentuate, magnify, or amplify any inherent differences in the handles. The method should detect even subtle differences in the handles which would become apparent only after long periods of work.

Thirty-six handles were fabricated for testing in this project. These consisted on all possible combinations of nine handle shapes and four handle sizes. The cross-sectional shapes evaluated were circular (C), circular with one flat side (D), circular with two flat sides (O), triangular (T), square (S) and rectangular with width to height rations of 1:1.25 (W), 1:1.50 (X), 1:1.75 (Y), and 1:2.0 (Z). The handle sizes evaluated were 7, 9, 11, and 13 cm in cross-sectional perimeter.

Phase 1 included six maximum force tests. These were thrust push and

pull, orthogonal push and pull, and torque extension and flexion. These tests have been described in detail in section IV of this report. The results indicate that the superior handle sizes and shapes are different for the six tests.

The analyses of the data collected for thrust push and pull tests indicate that triangular (T) handles and rectangular ratio 1:2.0 (Z) handles should be selected to maximize the thrust forces. Circular (C) and square (S) handles should be avoided when large thrust forces are to be exerted. For females, handles 9 cm or larger in perimeter (probably in the range of 9 to 11 cm) are superior for thrust forces. For males, handles in the 11 to 13 cm range appear to maximize the thrust forces possible. Where inter-actions between shape and size exist, the data also indicated that generally the triangular (T) and rectangular ratio 1:2.0 ratio (Z) handles in the 11 to 13 cm range for males and 9 to 11 cm range for females gave superior thrust forces.

The results of the orthogonal push and pull tasks are different. For the push task the circular (C) and circular with two flat sides (O) handles gave the highest forces, while the triangular (T) and rectangular ratio 1:2.0 (Z) handles gave the lowest. For the pull task rectangular ratio 1:1.50 (X) and triangular (T) handles were associated with high forces and the circular handles were associated with low forces. Therefore, these tests give very different results - what is high in one test is low in the other. Also, due to the differences in lever systems employed by the hand, there was a significant difference between the forces exerted in pull and those exerted in push. Finally, the large handle size had the effect of decreasing the force exerted in both tests.

The results of all analyses of the torque tests are extremely consistent. The handle shape was significant for both extension and flexion torque. The

rectangular ratio 1:2.0 (Z) handles had the highest torques, with the rectangular ratio 1:1.75 (Y) and the triangular (T) close behind. Consistently associated with low torques were the circular (C), square (S), circular with two flat sides (O), and the circular with one flat side (D) handles. With the exception of the square handle, torque was proportional to the maximum distance from the cross-sectional handle center to a point on the handle surface. Torque was also proportional to the size in the range of handle sizes tested. The presence of significant handle shape-size interaction terms indicates that caution should be exercised in selecting a shape-size combination for a particular handle.

The results of the analyses for phase 2 indicated no significance differences between any of the handles tested.

There are several conclusions that can be made from the results of the analyses of the phase 3 (guard evaluation) data. First, the radius of transition (in the range of radii tested) had no effect on the maximum force exerted. Second, for female subjects there is minimal improvement in the force exerted when the guard height was over 1.016 cm. Third, there is minimum improvement in the force exerted by male subjects when the guard height is over 1.524 cm. The same is true for all subjects. If tang guards were made high enough for male workers to maximize thrust push, they would be more than adequate for female subjects. Therefore, a guard height adequate for male subjects will be adequate for female subjects.

The basic overall conclusion from this is that guards 1.016 cm or less may be inadequate (depending on the gender) and guards 1.524 cm or more should be adequate for all workers. Inherent in these conclusions is the assumption that under the conditions of a slippery handle, the minimum guard height at which maximum force can be exerted is also the minimum height at which a tang guard becomes effective in preventing the hand from sliding off the handle.

The fact that this testing has determined a 1.016 cm high guard may be inadequate should be related to the heights of present meat packing knives featured in Figure I-1. Only one of these has a total guard height (higher than the effective height) over 1.016 cm. It would appear that present tang guards are, therefore, inadequate.

Handle shapes, sizes, and shape combinations were identified which were associated with the high forces on each of the six maximum force tests. The fatigue tests failed to indicate any differences between the 11 handles tested in this manner. The guard test indicated, for the range of radii tested, the radius of transition had no effect on maximum forces. However, guard height did affect the maximum force capability and a minimum effective guard height for males and one for females was determined. When compared with these minimum heights, most handles on knives currently available for meatpacking were found to be inadequate.

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APPENDIX A

MANUAL MATERIAL HANDLING HANDLE EVALUATION

AN EXAMINATION OF HANDLE SIZE AND SHAPE
FOR MANUAL MATERIAL HANDLING TASKS

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## OBJECTIVES

This research addresses itself to the question of whether or not signi-ficant differences exist in the muscular effort or force required by the hand to grip various handle designs during a manual material handling task. The manual materials handling task to be observed was the static lift of a tote box in two positions (Figure 1). The specific aim of this research project was to establish whether or not significant grip effort or force due to handle shape and size differences exist by monitoring and integrating the EMG of finger flexor muscles located in the right forearm.

## SIGNIFICANCE

There can be little doubt that overexertion represents a major industrial problem in the United States and other countries. It was expected that in 1980 over half a million workmen's compensation claims (NIOSH, 1981) would be filed citing overexertion as the cause. Obviously, overexertion does not result from sedentary duties, rather it results from physical activities such as manual materials handling, which put considerable loads on the human body.

The musculoskeletal system performs the tasks of concentrating, distributing and supporting loads throughout the body. In a review of literature by Herrin et al. (1974), seven potentially hazardous aspects of manual materials handling were identified, relating to the musculoskeletal systems:
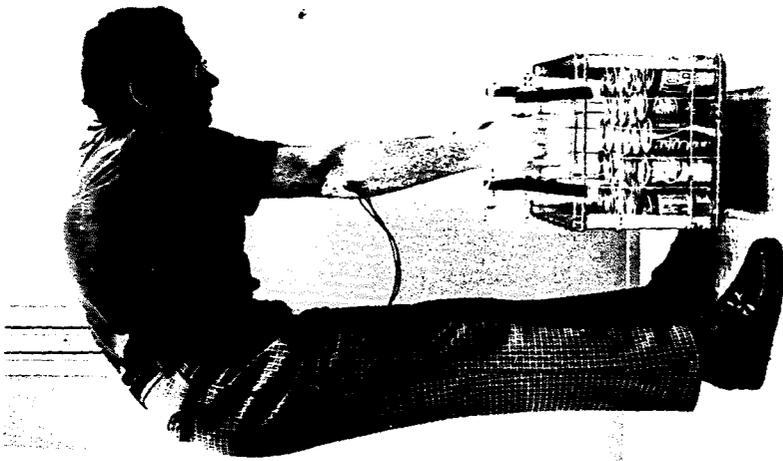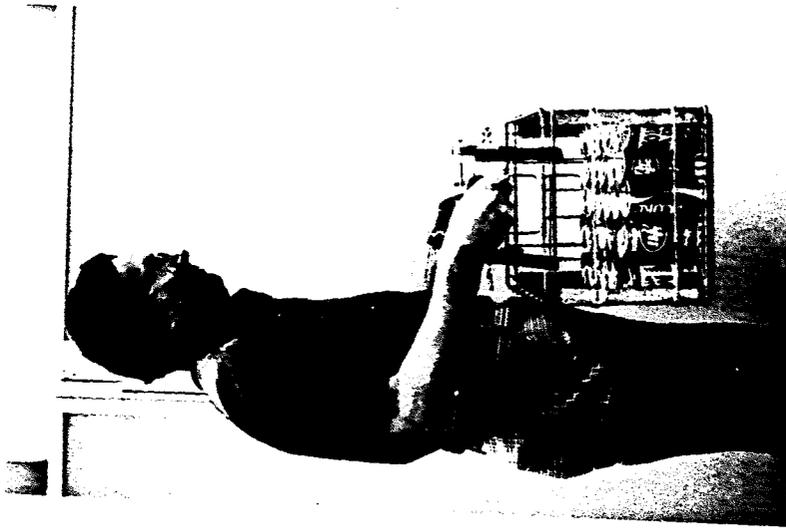
Figure 1.  Body Position.

High Position

Low Position

1) The weight to be lifted,

2) The position of the load relative to the person,

3) The lifting frequency.

4) The stability or awkwardness of the load,

5) The coupling of the load to the worker,

6) The workplace design,

7) The physical environment of the workplace.

"To date only the first three aspects have received sufficient attention in lifting injury research to form a strong basis for guidance." (NIOSH, 1981).

The coupling or handle design for manual materials handling tasks affects the maximum force that a worker can be expected to exert on the load he is lifting and the energy he expends in performing the task (NIOSH, 1981). Indeed, the shape of the handle determines the posture of the hand in the act of lifting and thereby the orientation of arm and shoulder muscles for the lift.     Handle design, therefore, may significantly affect both the muscles available for use in the lift and the actual amount of force exerted by each muscle.   It should be clear, that if a load is heavy, and muscles are not optimally available for use in lifting that load, injury due to overexertion may be more likely to occur.

This study seeks to fill a gap in the present state of knowledge on lifting handle design.  It provides information on handles with rectangular and triangular cross sections, as well as a comparison to cylindrical designs. Since the hand must adopt different muscle and bone orientations for each of the different handle designs, it is expected that there would be significant differences in grip effort or force required in using various handles.  This leads to conclusions regarding the desirability of the various cross-sectional designs versus the more conventional cylindrical handle.

## BACKGROUND

Although many textbooks and design books talk about handle design, they never address the problem of size and configuration to minimize effort, minimize fatigue, or maximize capability.  They neither specifically describe the design nor do they cite research that supports particular handle designs. Although considerable work has been done on grip strength, these studies do not address handle size, shape and force capability, fatigue, or muscular effort required to grasp.  There are, however, several that have examined some aspects of handle design.

Pheasant and O'Neill (1975) examined various screwdriver handle designs available in Great Britain and compared them with smooth and rough cylinders. They found no difference in torque capability of the handle shapes available. They did find that twist     capability increased as handle diameter increased from 1 to 3 cm with a leveling off tendency from 3 to 5 cm and a drop from 5 to 7 cm.  They found 5 cm to be the best diameter for cylindrical handles.

Patkin (1969) found that cylindrical handles needed a flat side to "improve control of possible twisting."  Mr. Patkin also used electromyography to compare "good and bad" handle designs.  Patkin has done considerable other work on handle designs but in the more delicate area of surgical instruments.

Ayoub and Lo Presti (1971) conducted a study to find the optimum size of cylindrical handles by use of electromyography.  They found that for cylindrical handles of approximately 2.54 to 6.35 centimeters in diameter, electromyography indicated no difference in effort, with dramatic increases outside of this range. They did a fatigue study and found the 6.35 diameter was inferior, dropping the optimal range of 2.54 to 5.08 cm.  This compares very closely to the Pheasant and O'Neill results.

In summary, some work has been done to establish the optimum size of cylindrical handles; however, little work has been done on other designs.

## METHOD

In order to test for differences in muscular effort due to handle configuration, nine cross-sectional shapes (see table 1) of four sizes each were tested. The sizes were based upon the cross-sectional perimeter which corresponds to the surface area of the handle. The perimeters used were 7, 9, 11, and 13 cm, which correspond to cylinders of approximately 2.23, 2.86, 3.50, and 4.14 cm diameter, respectively (.88, 1.13, 1.38, and 1.63 in inches).

The experimental design used was a two factor factorial one with blocking on subjects. The factors were handle shape with 9 levels and handle size with four levels.

The dependent variable utilized was an integrated electromyogram (EMG). The EMG was measured using a two electrode with ground setup, with the two electrodes placed adjacent to each other and over the muscles in the forearm associated with grasp (figure 2). This electrode positioning monitors the activity of the flexor muscles of the fingers.

The EMG was monitored with the subject holding a tote box in two positions. In the first position the subject bent over from the waist and hips and lifted the tote box. The arms were kept straight at the elbows. In the second position the individual stood straight and held the tote box in front of himself without letting the box come in contact with the body. The arms were kept at a right angle at the elbow (see Figure 1).

In both positions the subject lifted a tote box in which the right handle was changeable so that for each trial the right handle was different. The box was approximately 27.9 cm (11 in.) high by 33 cm (13 in.) wide by 43.2 (17 in.) long. The handles were 10.2 cm (4 in.) above the box or 38.1 cm (15 in.) above

| Description of the Cross Section | Cross Section |
|---|---|
| Circular (C) | |
| Circular with flat side (D) | |
| Circular with two flat sides (O) | |
| Triangular (T) | |
| Square        1:1.00 (S) | |
| Rectangular   1:1.25 (W) | |
| Rectangular   1:1.50 (X) | |
| Rectangular   1:1.75 (Y) | |
| Rectangular   1:2.00 (Z) | |

Table 1    Handle Descriptions

Figure 2.  Electrode Placement

the bottom of the box. The box was actually a welded wire milk case loaded with soft drink cans containing lead shot. The box weighed 9.07 kg (20 lb) and the load was evenly distributed throughout.

In addition to the data on EMG gathered, eleven anthropometric measurements of the subjects' hands and arms were taken by direct measurement. These measurements included hand thickness, hand breadth, hand circumference, hand length, fist circumference, palm length and forearm circumference, as described in NASA anthropometric Source Book, Vol. II (NASA, 1978). The four other measurements were grip diameter, finger circumference, forefinger length and thumb crotch length. The measurements taken are shown in figure 3. These were later used along with the analysis of the EMG data.

A total of 7 male subjects was used for this experiment. They ranged in age from 20 to 40 years old and were all in good health. None of the subjects was currently working in material handling, although some had had related work in the past.

## RESULTS

The data for the EMG of the low or bent-over position and the data for the high or upright position were analyzed separately but in an identical manner. First, an analysis of variance was conducted on each set. Next, a Tukey's paired comparison was used to compare the means of the nine shapes, the means of the four sizes, and finally, the means of the 36 shape size combinations were compared using a Scheffe's test.

The analysis of variance showed all factors and interactions included in the model to be significant at $\alpha = .05$ for both the low and the high positions (tables 2 and 3). Tables 4, 5, 6, 7, 8 and 9 show the results of the Tukey's and Scheffe's tests.
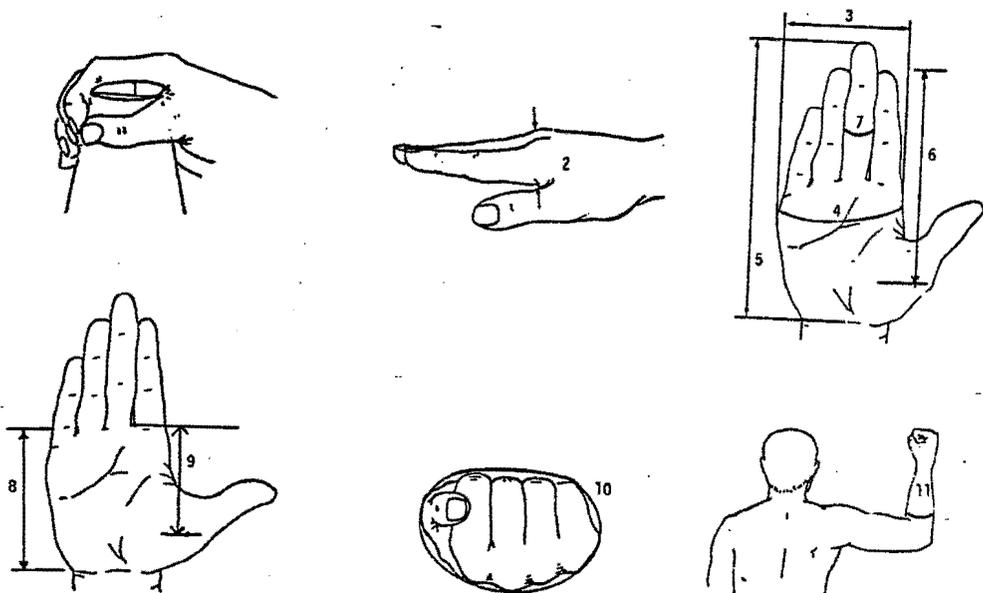
1 - <u>Grip Diameter, Inside</u>. The diameter of the widest level of a cone which the subject can grip with his thumb and forefinger touching.

2 - <u>Hand Thickness</u> (Thickness at Metacarpal III). The thickness of the metcarpal-phalangeal joint of the middle finger. (NASA 1978)

3 - <u>Hand Breadth</u>. The breadth of the hand as measured across the distal ends of the metacarpal bones. (NASA 1978)

4 - <u>Hand Circumference</u>. The circumference of the hand measured around its knuckles. (NASA 1978)

5 - <u>Hand Length</u>. The distance from the base of the hand to the top of the middle finger measured along the long axis of the hand. (NASA 1978)

6 - <u>Forefinger Length</u>. The distance from the metacarpal-phalangeal joint at the thumb to the tip of the forefinger (digit II).

7 - <u>Finger Circumference</u>. The circumference of the middle finger taken at the 2nd phalanageal.

8 - <u>Palm Length</u>. The distance from the base of the hand to the furrow where the middle finger folds upon the palm.

9 - <u>Thumb Crotch Length</u>. The distance from the metacarpal-phalangeal joint of the thumb to the notch between the 1st and 2nd fingers.

10 - <u>Fist Circumference</u>. The circumference of the clenched fist (the thumb lying across the end of the fist (measured with the tape passing over the thumb and knuckles).

11 - <u>Forearm Circumference, Flexed</u>. The maximum circumference of the lower arm bent, the upper arm horizontal, and the fist clenched. (NASA 1978)

Figure 3.  Anthropometric Measures

TABLE 2

Analysis of Variance of the

Low Position Integrated EMG

| SOURCE OF VARIATION | DEGREES OF FREEDOM | SUMS OF SQUARES | MEAN SQUARES | F RATIO |
|---|---|---|---|---|
| 1 Subjects | 6 | 45068.21 | 7511.3 | 745.53 * |
| 2 Shape | 8 | 664.36 | 83.05 | 8.24 * |
| 3 Size | 3 | 367.25 | 122.42 | 12.15 * |
| 12 Subject-Shape | 48 | 5300.73 | 110.43 | 10.96 * |
| 13 Subject-Size | 18 | 1619.48 | 89.97 | 8.93 * |
| 23 Shape-Size | 24 | 3611.27 | 150.47 | 14.93 * |
| 123 Subject-Shape-Size | 144 | 15096.21 | 104.83 | 10.40 * |
| Within Replicates | 252 | 2538.97 | 10.08 | |
| Total | 503 | 74266.50 | | |

*Significant at $\alpha = 0.05$ level.

# TABLE 3
## Analysis of Variance of the
## High Position Integrated EMG

| SOURCE OF VARIATION | DEGREES OF FREEDOM | SUMS OF SQUARES | MEAN SQUARES | "F" RATIO |
|---|---|---|---|---|
| 1 Subjects | 6 | 60886.13 | 10147.69 | 1117.32 * |
| 2 Shape | 8 | 833.17 | 104.15 | 11.47 * |
| 3 Size | 3 | 338.06 | 112.69 | 12.41 * |
| 12 Subject-Shape | 48 | 4306.62 | 89.72 | 9.88 * |
| 13 Subject-Size | 18 | 1983.17 | 110.18 | 12.13 * |
| 23 Shape-Size | 24 | 2500.89 | 104.20 | 11.47 * |
| 123 Subject-Shape-Size | 144 | 13945.75 | 96.85 | 10.66 * |
| Within Replicates | 252 | 2288.70 | 9.08 | |
| Total | 503 | 87082.44 | | |

*Significant at $\alpha$ = 0.05 level.

TABLE 4

Results of the Tukey's Test for
Handle Size for the Low Position

| Handle Size (cm) | 7 | 11 | 9 | 13 |
|---|---|---|---|---|
| Mean Newtons | 29.09 | 29.64 | 30.64 | 31.29 |

TABLE 5

Results of the Tukey's Test for
Handle Shape for the Low Position

| Handle Shape | W 1:1.25 | Z 1:2 | D | X 1:1.5 | S 1:1 | C | T | O | Y 1:1.75 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 28.71 | 28.96 | 29.36 | 29.58 | 29.83 | 30.51 | 30.64 | 31.46 | 32.44 |

## TABLE 6

### Results of the Scheffe's Test for Handle Shpae and Size for the Low Position

| Handle Shape and Size | W 9 | Y 9 | O 7 | O 13 | O 11 | S 9 | T 13 | C 11 | C 9 | T 7 | O 9 | Y 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 27.82 | 27.83 | 27.98 | 28.26 | | | | | 32.12 | 32.45 | 39.08 | 43.86 |

## TABLE 7

### Results of the Tukey's Test for Handle Size for the High Position

| Handle Size (cm) | 7 | 11 | 9 | 13 |
|---|---|---|---|---|
| Mean Newtons | 32.83 | 33.30 | 33.79 | 35.02 |

## TABLE 8

### Results of the Tukey's Test for Handle Shape for the High Position

| Handle Shape | Z 1:2 | W 1:1.25 | X 1:1.5 | S 1:1 | D | C | T | O | Y 1:1.75 |
|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 32.27 | 32.53 | 32.81 | 33.02 | 33.21 | 34.00 | 34.28 | 34.94 | 36.53 |

# TABLE 9

### Results of the Scheffe's Test for Handle Shape and Size for the High Position

| Handle Shape and Size | Z 9 | Z 11 | X 7 | X 9 | W 13 | Y 7 | Y 11 | C 9 | O 9 | Y 13 |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean Newtons | 31.15 | 31.39 | 31.57 | 31.67 | 31.95 | 31.97 | 35.24 | 35.48 | 39.95 | 46.71 |

TABLE 10

Analysis of Covariance of the Low
Position Ingegrated EMG with Grip
Diameter, Hand Length, and Hand
Circumference as Concomitant
Variables

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F RATIO |
|---|---|---|---|---|
| Mean | 6136.45 | 1 | 6136.45 | 71.40 |
| J Shape | 755.64 | 8 | 94.46 | 1.10 |
| K Size | 322.32 | 3 | 107.44 | 1.25 |
| JK Shape-Size | 4045.13 | 24 | 168.55 | 1.96 |
| Covariates | 39437.84 | 3 | 13145.95 | 152.94* |
| Grip Diameter | 1179.18 | 1 | 1179.18 | 13.72* |
| Hand Length | 12632.29 | 1 | 12632.29 | 146.97* |
| Hand Circumference | 30132.38 | 1 | 30132.38 | 350.57* |
| R(JK) | 39967.78 | 465 | 85.95 | |

*Significant at $\alpha = 0.05$ level.

## TABLE 11

### Analysis of Covariance of the High Position Integrated EMG with Grip Diameter and Forearm Circumference as Concomitant Variables

| SOURCE | SUM OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F RATIO |
|---|---|---|---|---|
| Mean | 15588.31 | 1 | 15588.31 | 100.25 |
| J Shape | 1550.94 | 8 | 193.87 | 1.25 |
| K Size | 309.94 | 3 | 103.31 | 0.66 |
| JK Shape-Size | 2806.88 | 24 | 116.95 | 0.75 |
| Covariates | 20869.00 | 2 | 10434.50 | 67.10 * |
| Grip Diameter | 7142.96 | 1 | 7142.96 | 45.94 * |
| Forearm Circumference | 2904.81 | 1 | 2904.81 | 18.68 * |
| R(JK) | 72463.38 | 466 | 155.50 | |

*Significant at $\alpha = 0.05$ level.

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In all of the Tukey and Scheffe's tests the lower near values are interpreted as better or preferred. This is because a lower integrated EMG is associated with less force applied by those muscles and therefore less effort.

The results of the analyses of variance indicate a significant difference between shapes, sizes and the shape-size interactions (Tables 2 and 3) for both positions. The Tukey's and Scheffe's tests on these differences are not easily interpreted. The results of the Tukey's tests on the size are very similar for the two positions. In both cases the integrated EMG was lowest for a perimeter of 7 cm and highest for one of 13 cm. However, the EMG was lower for 11 cm than for 9 cm. For the low position the EMG for 7 cm was significantly lower than that of 9 cm and 13 cm but not significantly lower than that of 11 cm. Also, the 11 cm and 9 cm were not significantly different nor were 9 cm and 13 cm, but 11 cm was significantly less than 13 cm. For the high position there was no significant difference between 7 cm, 11 cm, and 9 cm, but all were significantly less than 13 cm.

The Tukey's tests on handle shapes for the low position (Table 5) indicated that the integrated EMG for handle W was significantly less than that of O and Y. Also, the EMG's of handles W, Z, P, and X were significantly less than that of handle Y. For the high position (Table 8) the EMG of Z was significantly less than those of O and Y. Also, the EMG of handles Z, W, X, and S were significantly less than that of handle Y.

Tukey's tests would have been conducted on the shape-size interaction except that tables available for the studentized range statistic (q) were not available for comparing 36 means (20 is the highest in available tables). A Scheffe's test was, therefore, used to compare the interaction means for the low and high positions (Tables 6 and 9).

For the low position, the Scheffe's test (Table 6 ) showed a significant difference of handles W-9 cm, Y-9 cm, O-7 cm, and O-13 cm from handles O-9 cm and Y-13 cm. The Scheffe's test for the high position (Table 9) indicated handles Z-9 cm, Z-11 cm, X-7 cm and X-9 cm had significantly lower integrated EMG's than handles O-9 cm and Y-13 cm. The primary result of these tests is to demonstrate that handles O-9 cm and Y-13 cm required significantly more muscular effort to hold by the subjects tested.

Finally, an analysis of covariance was conducted with the most promising of the anthropometric measurements used as concomitant variables, hand length, grip diameter, and hand circumference (measurements 10, 5 and 4, respectively, from Figure 3). For the high position the concomitant variables were grip diameter and forearm circumference (measurements 10 and 11, respectively, from Figure 3).

In contrast to the results of the analysis of variance, analysis of co-variance with hand anthropometric measurements as concomitant variables showed no significant differences among shape-size interaction. The concomitant variables were, however, significant. It should be noted that the analysis of variance model had subject with its interactions as blocking variables where the subject factor could not be included in the covariance model because of problems of singularity.

## Conclusions

The first conclusion is that the integrated EMG was very effective in indicating subtle differences in muscular effort due to handle configuration. It should, however, be only one of several tests, such as fatigue and maximum force capability, combined to give a complete evaluation of a handle configura-tion. Even then, EMG is most effective in giving relative differences and not absolutes.

Conclusions about the handle sizes and shapes tested are numerous if

sometimes confusing.  The 7 cm handles seemed to have the lowest integrated EMG scores and the 13 cm handles the opposite.  This would indicate that, of those tested, the smaller handles are better.  The results on the 9 cm and 11 cm handles would indicate just the opposite.  However, since for neither position were 9 cm handles significantly different from 11 cm handles, this order is of little consequence.  A safe conclusion is that 13 cm handles were significantly worse than the others except for the 9 cm handle in the low position for which there was no difference.

The differences between the handle shapes were interesting.  In both positions the Y and O handles had the highest integrated EMG, and the Z and W handles had the lowest.  In the low case W is significantly lower than O and Y and the high case Z is significantly lower than O and Y handles.  In both cases Z, W, and X handles are significantly less than Y handles.  This is difficult to interpret because W, X, Y, and Z handles are all rectangular.  They differ only in the ratio of the width to the height from 1:1.25 to 1:2.0.  The Y handles have a ratio of 1:1.75, which is not on one end of this range.  It therefore seems illogical that Y handles would be worse than the others. A possible explanation is that the dimensions of the Y handles were just inappropriate for the bones of the fingers and hands of the seven subjects tested. This indicates that more testing is needed on a wider variety of subjects.

As was stated earlier, the analysis of covariance for the low and high positions (Tables 10 and 11) indicated significant concomitant variables and no significance for shape, size, or the shape-size interaction.  The primary reason for this is evident upon examining the estimates of error variance used in the various models.  For the analysis of variance models these estimates were 10.08 and 9.08 for the low and high positions, respectively, while those for the covariance analysis were 85.95 and 155.50.  The covariance analysis

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estimates of the error variance are at least eight times larger than those for the analysis of variance. The purpose of including a concomitant variable and of including a blocking variable in the design and analysis of an experiment are often the same. This purpose is to account for unexplained variation in the error term and thereby refine the estimate of error variance. In this case it appears that including the blocking variable subjects with its interactions was more effective than using concomitant variables in an analysis of covariance. The covariance analysis did, however, demonstrate the relationship of hand anthropometric measurements to the grasp of different handles.

These analyses of variance and analyses of covariance demonstrate that performance characteristics on handles are affected by the individual and by the characteristics of that individual. They show that size and shape have a bearing on grasp effort and that much more extensive research is needed to make definitive statements about which shape-size configuration is "best."

<div align="center">

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</div>

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APPENDIX B

HANDLE DIMENSIONS
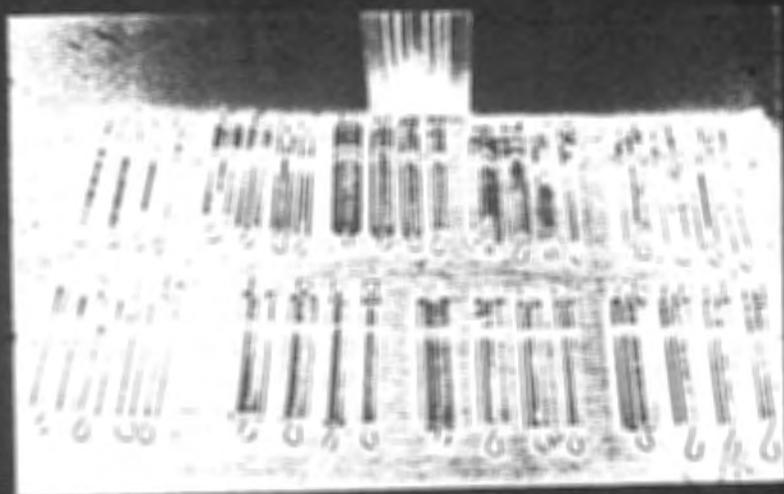
Figure B-1. All of the Handles Fabricated for this Study
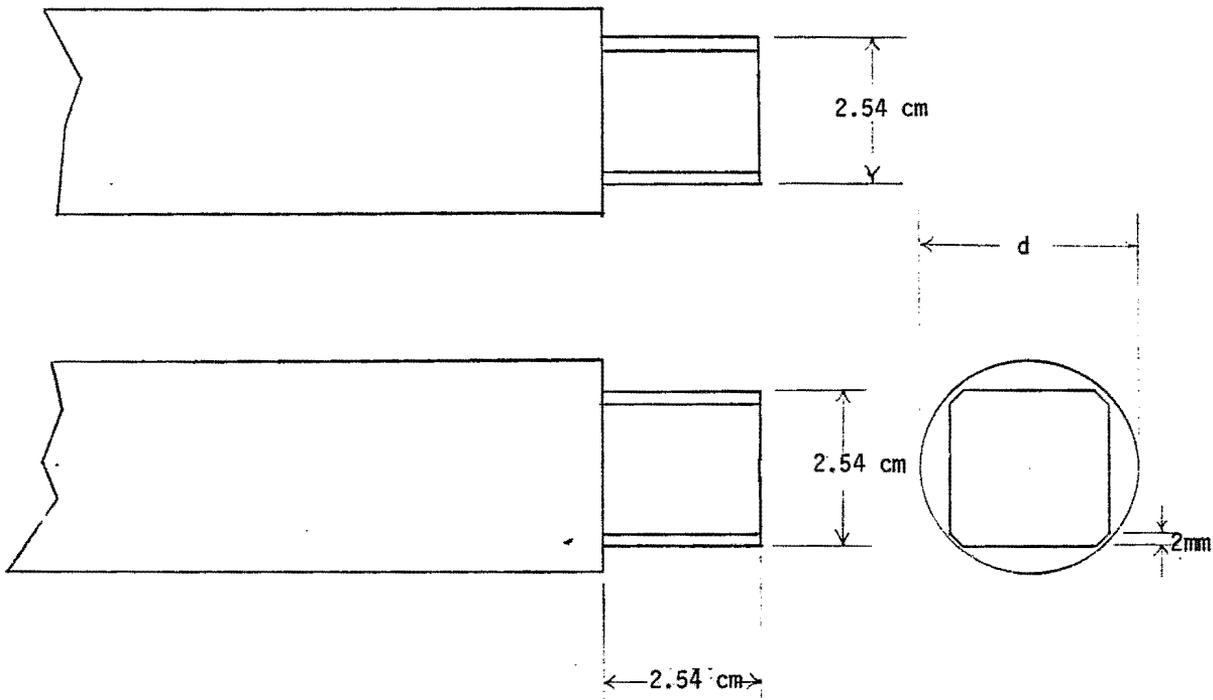
The ends of all handles are 1" cubes.

Circumferences of all handles are the same.

| $C_{cm}$ | $C_{in}$ | $d_{cm}$ | $d_{in}$ |
|------|-------|-------|-------|
| 7 | 2.756 | 2.228 | 0.877 |
| 9 | 3.543 | 2.865 | 1.128 |
| 11 | 4.331 | 3.501 | 1.379 |
| 13 | 5.118 | 4.138 | 1.629 |

Figure B-2. Circular Cross Section Handle (C)
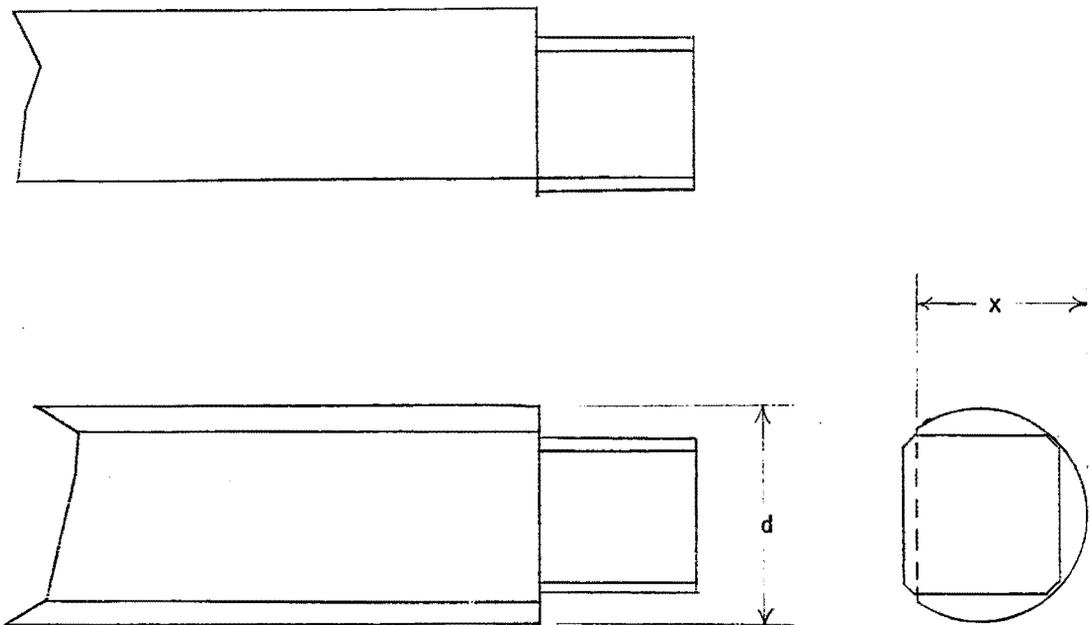
| $C_{cm}$ | $r = \dfrac{d}{x}$ | $d_{cm}$ | $d_{in}$ | $x_{cm}$ | $x_{in}$ |
|---|---|---|---|---|---|
| 7 | 1.25 | 2.322 | 0.9142 | 1.858 | 0.7313 |
| 9 | 1.25 | 2.986 | 1.1756 | 2.388 | 0.9450 |
| 11 | 1.25 | 3.649 | 1.4366 | 2.919 | 1.1493 |
| 13 | 1.25 | 4.313 | 1.6980 | 3.450 | 1.3584 |

Figure B-3. Circular with Flat Side Cross Section Handle (D)
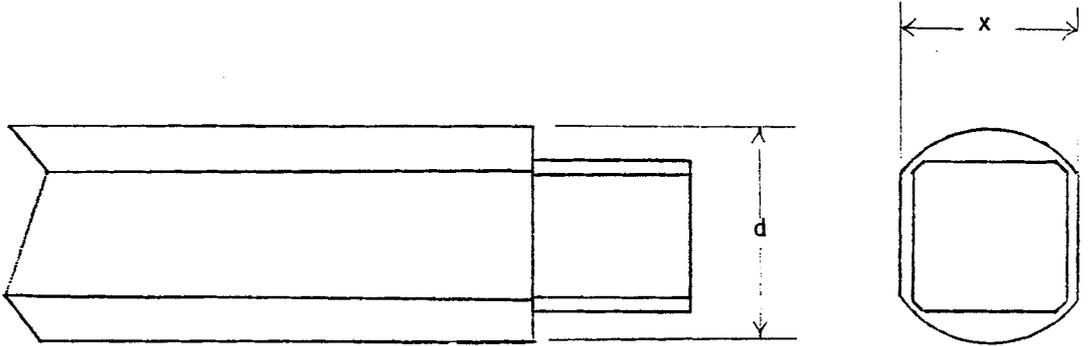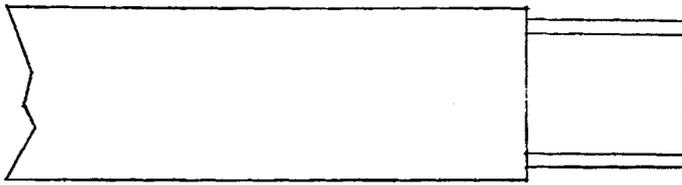
| $C_{cm}$ | $r = \dfrac{d}{x}$ | $d_{cm}$ | $d_{in}$ | $x_{cm}$ | $x_{in}$ |
|---|---|---|---|---|---|
| 7 | 1.25 | 2.2917 | 0.9022 | 1.8334 | 0.7218 |
| 9 | 1.25 | 2.9464 | 1.1600 | 2.3571 | 0.9280 |
| 11 | 1.25 | 3.6011 | 1.4178 | 2.8810 | 1.1342 |
| 13 | 1.25 | 4.2560 | 1.6756 | 3.4048 | 1.3405 |

Figure B-4. Circular with Flat Sides Cross Section Handle (0)
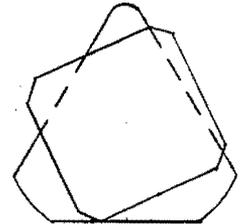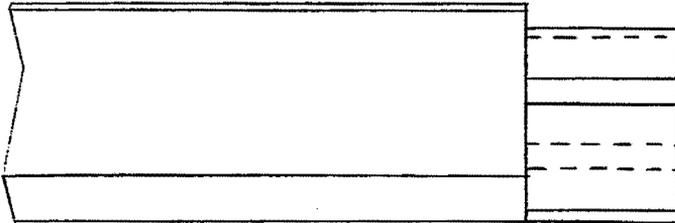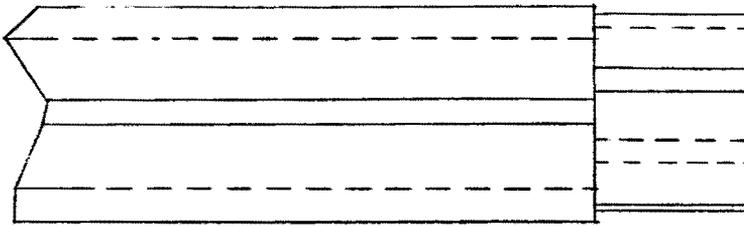
All rounds .635 cm
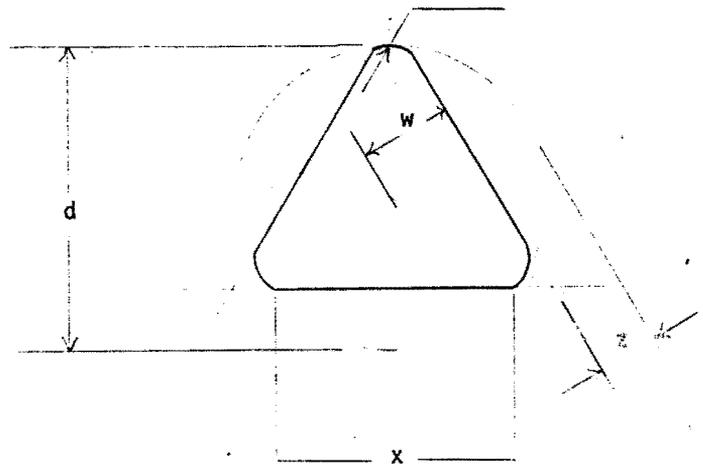
| C_cm | x_cm | x_in | d_cm | d_in | w_cm | w_in | z_cm | z_in |
|------|------|------|------|------|------|------|------|------|
| 7 | 1.003 | 0.395 | 2.428 | 0.956 | 0.9246 | 0.364 | 0.289 | 0.114 |
| 9 | 1.670 | 0.658 | 3.198 | 1.259 | 1.117 | 0.440 | 0.482 | 0.190 |
| 11 | 2.337 | 0.920 | 3.986 | 1.562 | 1.310 | 0.516 | 0.674 | 0.265 |
| 13 | 3.003 | 1.182 | 4.738 | 1.865 | 1.502 | 0.591 | 0.867 | 0.341 |

Figure B-5.   Triangular Cross Section Handle (T)
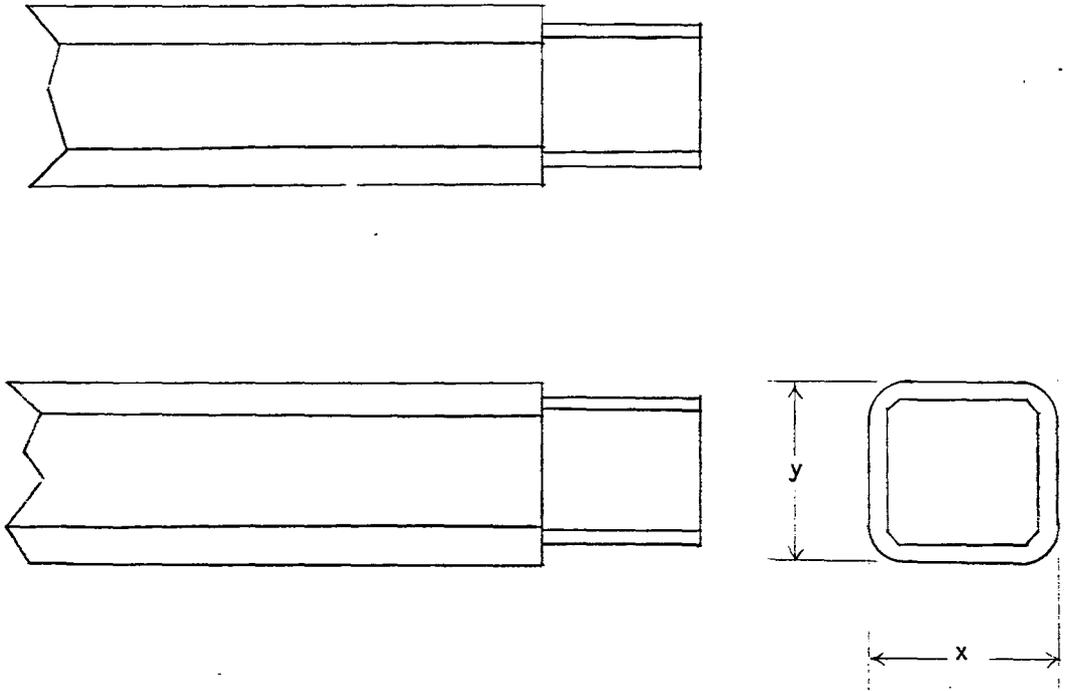
| $C_{cm}$ | $r = \frac{y}{x}$ | $x_{cm}$ | $x_{in}$ | $y_{cm}$ | $y_{in}$ |
|------|------|-------|-------|-------|-------|
| 7 | 1.0 | 2.023 | 0.796 | 2.023 | 0.796 |
| 9 | 1.0 | 2.523 | 0.993 | 2.523 | 0.993 |
| 11 | 1.0 | 3.023 | 1.190 | 3.023 | 1.190 |
| 13 | 1.0 | 3.523 | 1.387 | 3.523 | 1.387 |

Figure B-6.  Square Cross Section Handle (S)
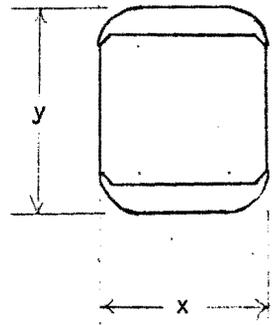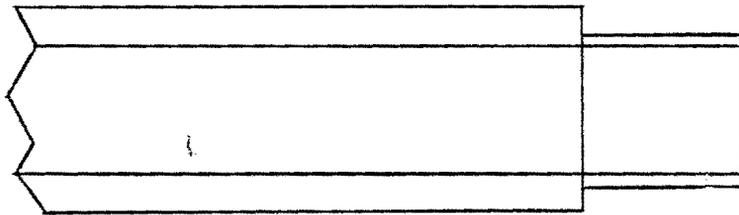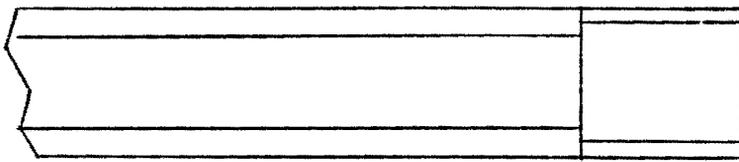
| $C_{cm}$ | $r = \frac{y}{x}$ | $x_{cm}$ | $x_{in}$ | $y_{cm}$ | $y_{in}$ |
|------|------|-------|-------|-------|-------|
| 7 | 1.25 | 1.798 | 0.708 | 2.247 | 0.885 |
| 9 | 1.25 | 2.242 | 0.883 | 2.803 | 1.103 |
| 11 | 1.25 | 2.687 | 1.058 | 3.358 | 1.322 |
| 13 | 1.25 | 3.131 | 1.233 | 3.914 | 1.541 |

Figure B-7.  Rectangular Cross Section Handle (W)
             r = 1.25
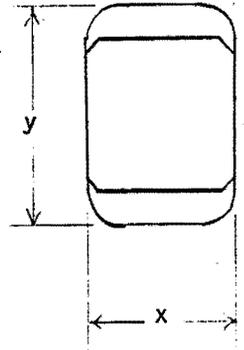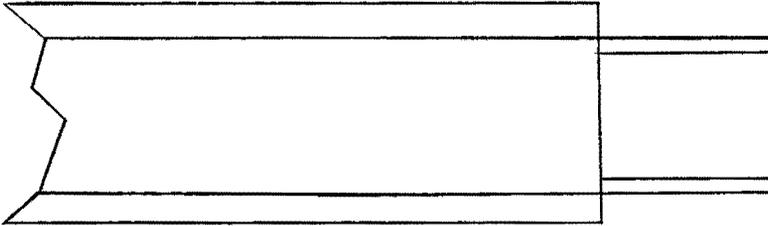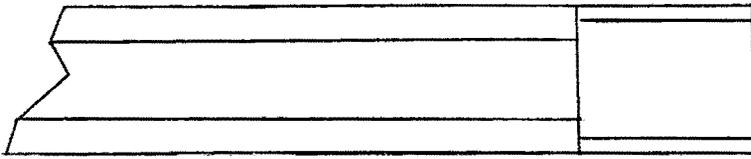
| $C_{cm}$ | $r = \frac{y}{x}$ | $x_{cm}$ | $x_{in}$ | $y_{cm}$ | $y_{in}$ |
|---|---|---|---|---|---|
| 7 | 1.50 | 1.618 | 0.637 | 2.427 | 0.956 |
| 9 | 1.50 | 2.018 | 0.795 | 3.027 | 1.192 |
| 11 | 1.50 | 2.418 | 0.952 | 3.627 | 1.428 |
| 13 | 1.50 | 2.818 | 1.109 | 4.227 | 1.664 |

Figure B-8.   Rectangular Cross Section Handle (X)
r = 1.50
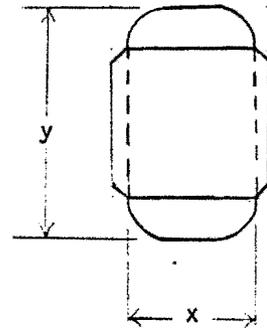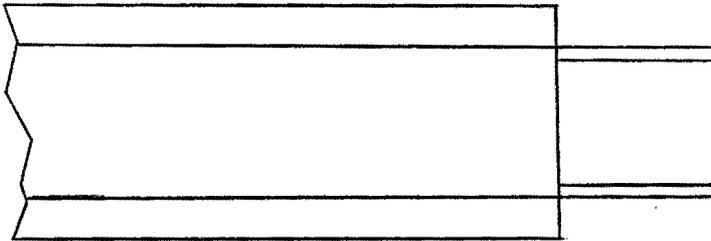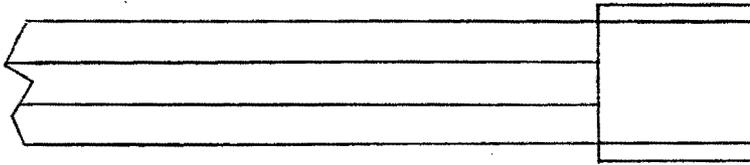
| $C_{cm}$ | $r = \dfrac{y}{x}$ | $x_{cm}$ | $x_{in}$ | $y_{cm}$ | $y_{in}$ |
|---|---|---|---|---|---|
| 7 | 1.75 | 1.471 | 0.579 | 2.574 | 1.013 |
| 9 | 1.75 | 1.835 | 0.722 | 3.211 | 1.264 |
| 11 | 1.75 | 2.198 | 0.865 | 3.847 | 1.515 |
| 13 | 1.75 | 2.563 | 1.009 | 4.483 | 1.765 |

Figure B-9.   Rectangular Cross Section Handle (Y)
r = 1.75
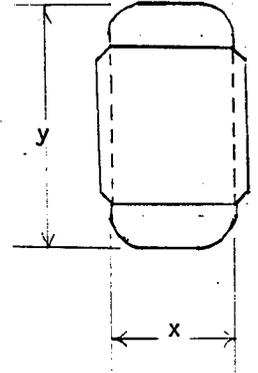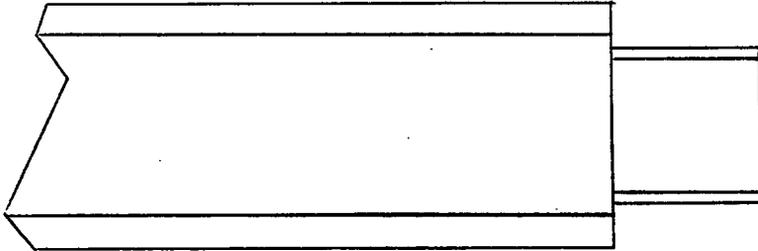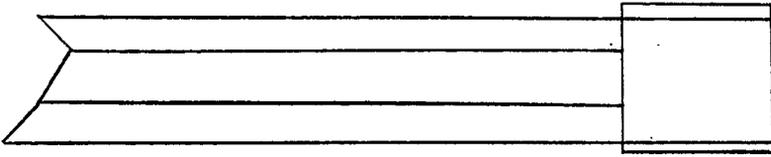
| $C_{cm}$ | $r = \frac{y}{x}$ | $x_{cm}$ | $x_{in}$ | $y_{cm}$ | $y_{in}$ |
|---|---|---|---|---|---|
| 7 | 2.0 | 1.348 | 0.531 | 2.697 | 1.062 |
| 9 | 2.0 | 1.682 | 0.662 | 3.363 | 1.324 |
| 11 | 2.0 | 2.015 | 0.793 | 4.030 | 1.587 |
| 13 | 2.0 | 2.348 | 0.925 | 4.697 | 1.849 |

Figure B-10.  Rectangular Cross Section Handle (Z)
r = 2.0

APPENDIX C

GUARD DIMENSIONS
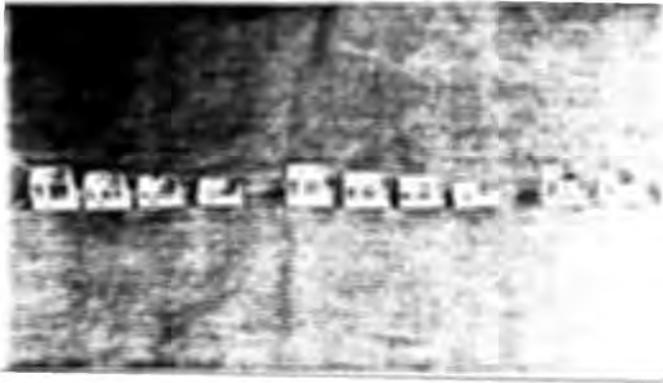
Figure C-1. Picture of the Guards Tested and the Handle
with One of the Guards Mounted for Testing
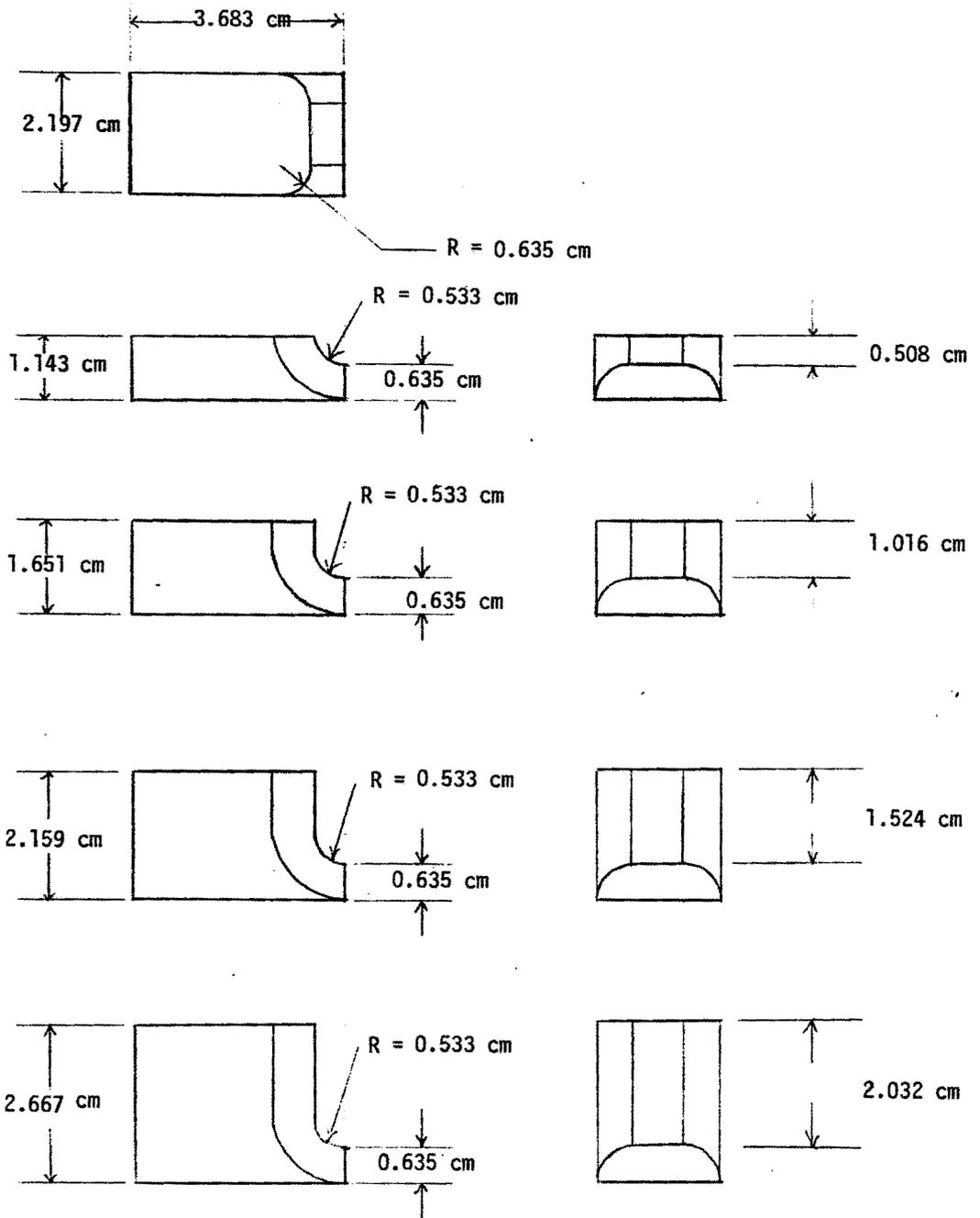
Figure C-2. Knife Handle Guard.   Round is 0.533 cm
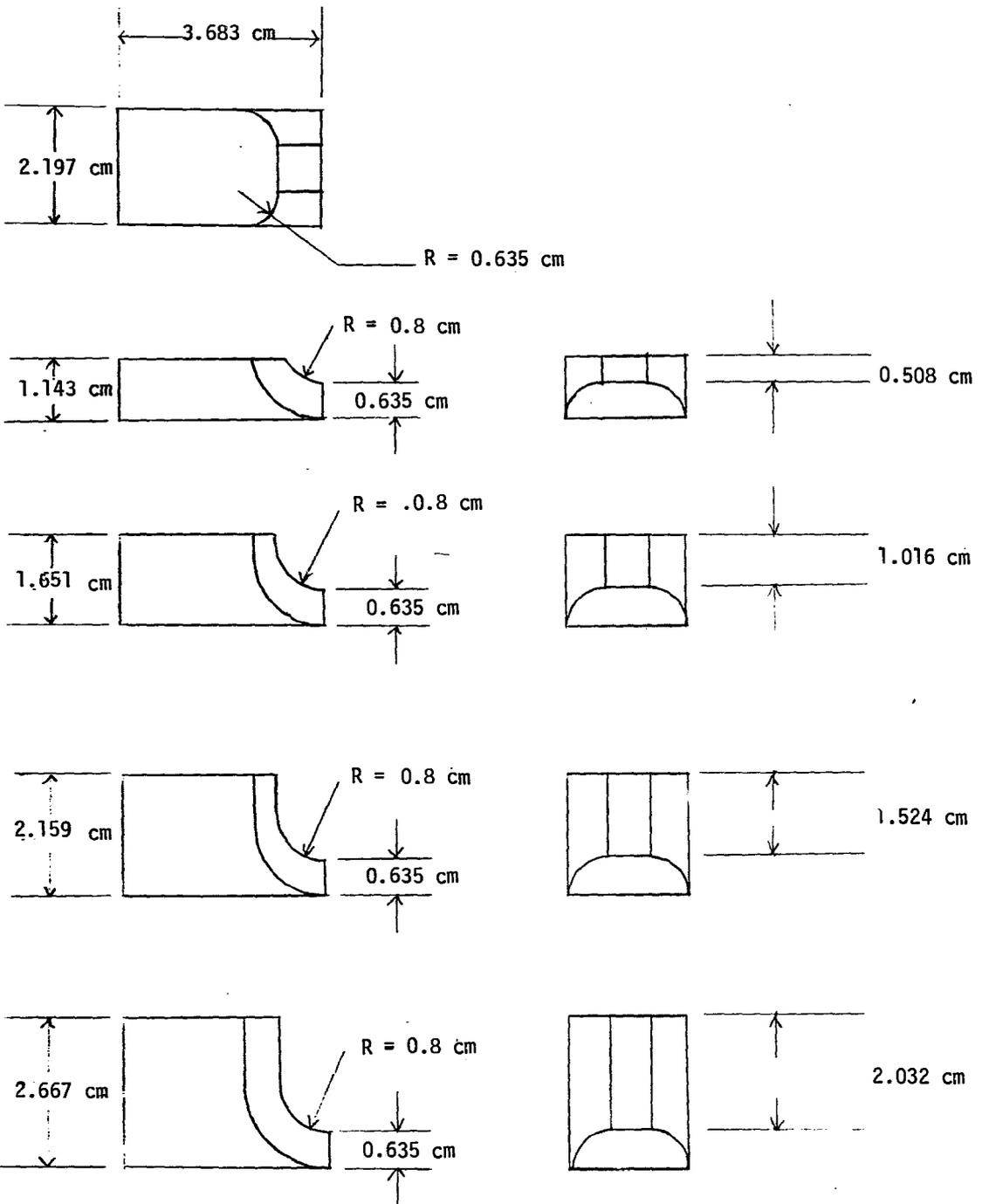
Figure C-3.   Knife Handle Guard.   Round is   0.8 cm
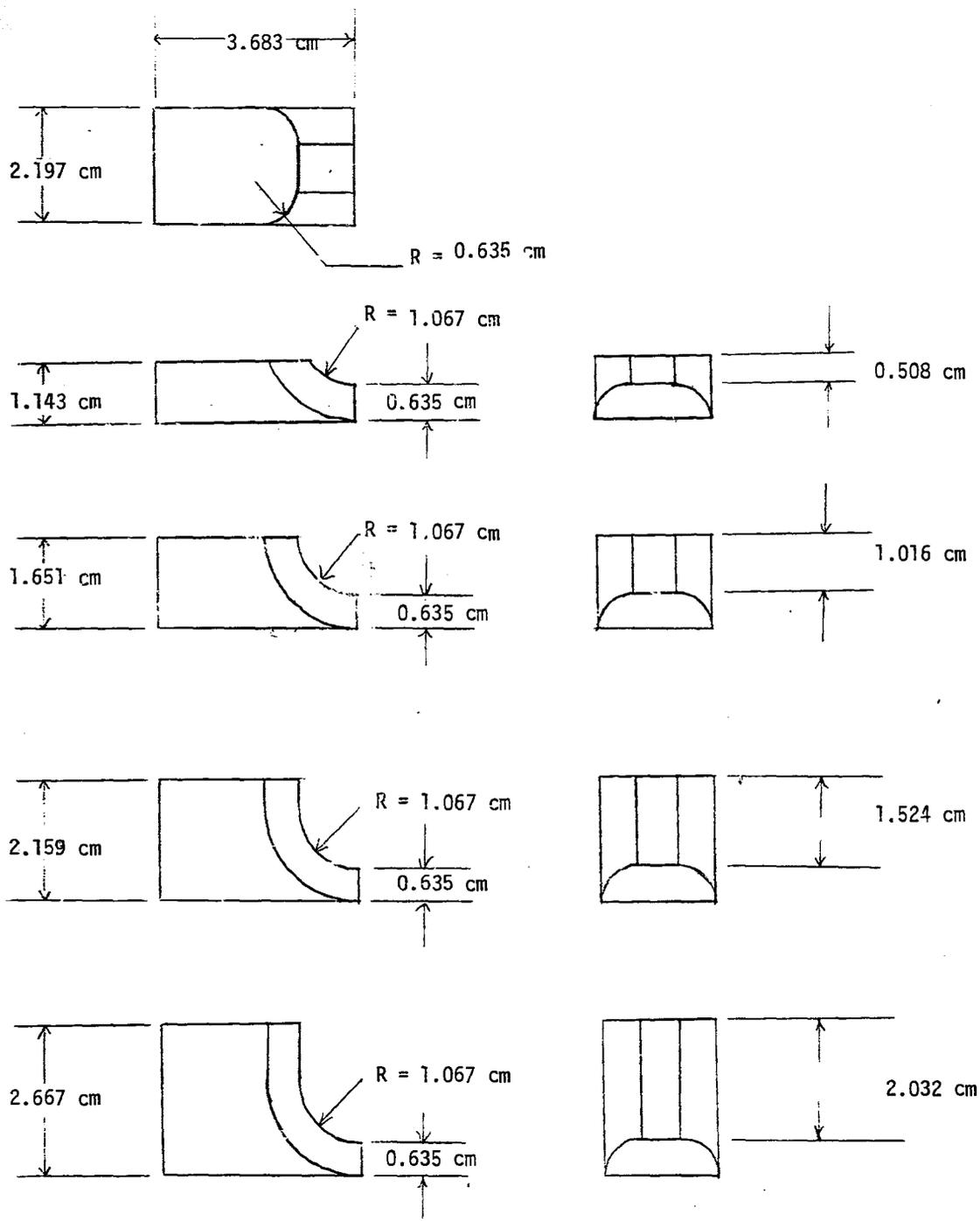
Figure C-4. Knife Handle Guard. Round is .1.067 cm
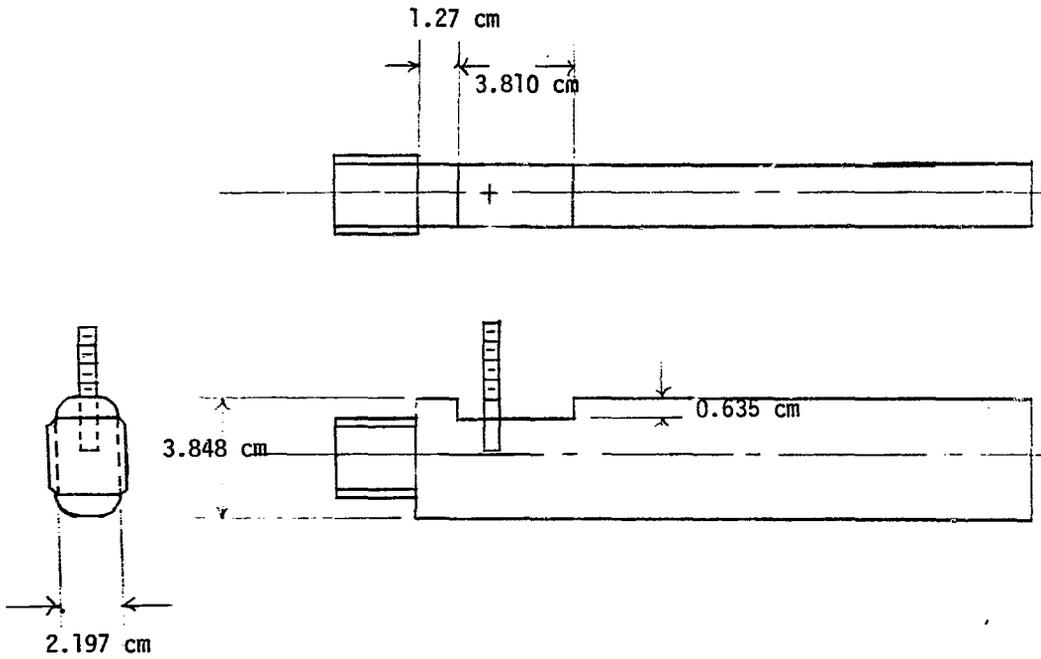
Figure C-5. Knife Handle with Guard Mount
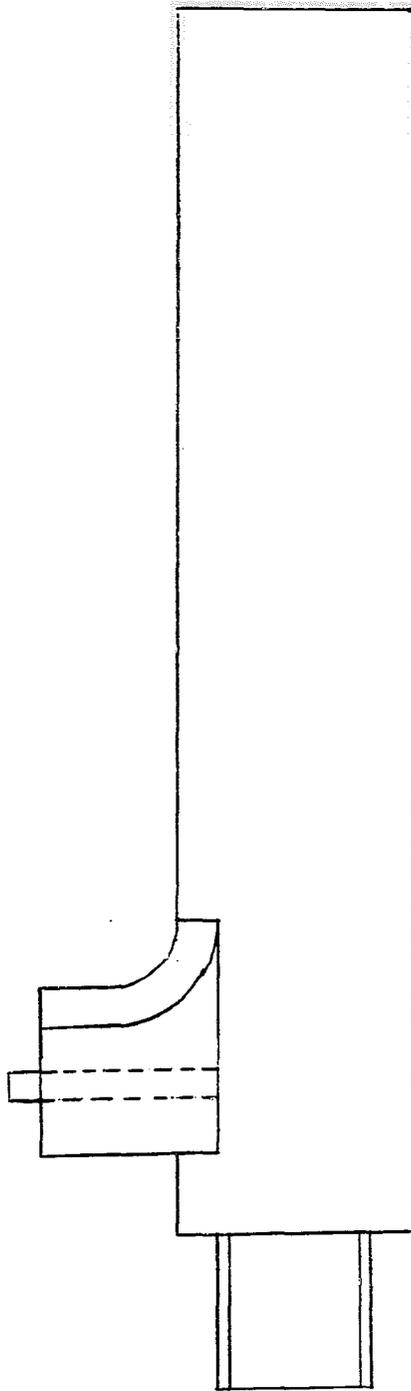
Figure C-6.   Knife Handle with Guard in Place

APPENDIX D

ANTHROPOMETRIC MEASUREMENTS

Anthropometric measurements of the subjects' hands and arms were taken by direct measurement.  For the phase one and phase two portions of this project, eleven anthropometric measurements were made and recorded. These measurements included hand thickness, hand breadth, hand circumference, hand length, fist circumference, palm length and forearm circumference, as described in NASA anthropometric Source Book, Vol. II (NASA, 1978). The four other measurements were grip diameter, finger circumference, forefinger length and thumb crotch length.

Three anthropometric measurements were made and recorded for the subjects participating in phase three of this project.  These measurements were all taken of the forefinger and included the thickness of the first phalanges, the second phalanages and the first-second phalangeal joint.

1 - <u>Grip Diameter, Inside</u>. The
    diameter of the widest level
    of a cone which the subject
    can grasp with his thumb and
    forefinger touching.
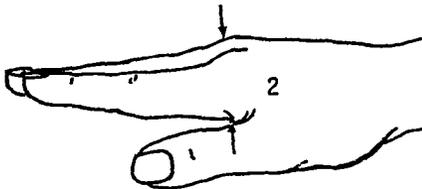


2 - <u>Hand Thickness</u> (Thickness at
    <u>Metacarpale III</u>). The thick-
    ness of the metacarpal-phalangeal
    joint of the middle finger.
    (NASA, 1978)
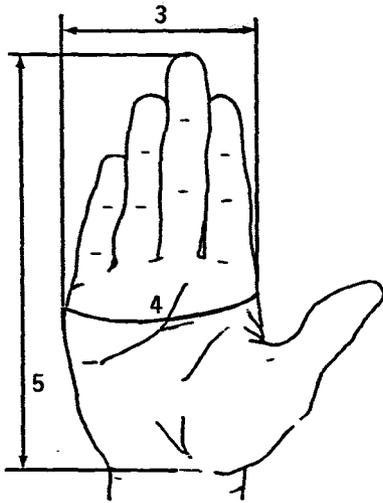
3 - Hand Breadth. The breadth of
the hand as measured across
the distal ends of the meta-
carpal bones. (NASA, 1978)

4 - Hand Circumference. The cir-
cumference of the hand
measured around its knuckles.
(NASA, 1978)

5 - Hand Length. The distance
from the base of the hand to
the top of the middle finger
measured along the long axis
of the hand. (NASA, 1978)
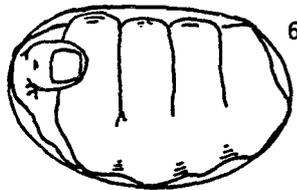


6 - Fist Circumference. The circum-
ference of the clenched fish (the
thumb lying across the end of the
fist) measured with the tape
passing over the thumb and the
knuckles.
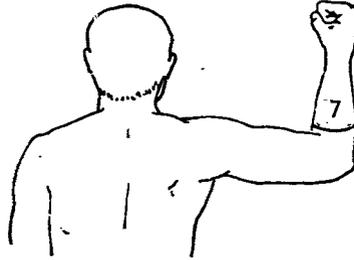
7 - Forearm Circumference, Flexed.
The maximum circumference of the
lower arm bent, the upper arm
horizontal, and the fist clenched.
(NASA, 1978).
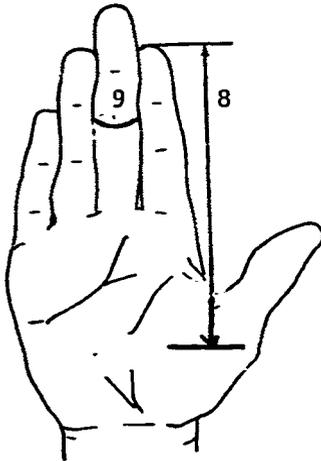


8 - Forefinger Length. The
distance from the meta-
carpal-phalangeal joint
at the thumb to the tip
of the forefinger (digit II).

9 - Finger Circumference. The
circumference of the middle
finger taken at the 2nd
phalangeal.
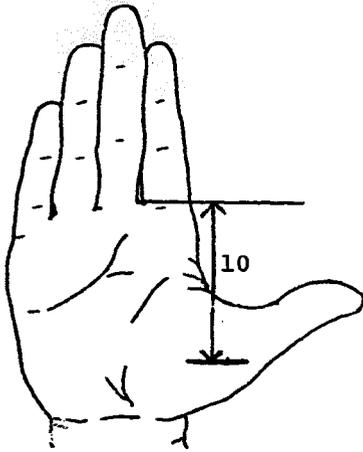
10 - <u>Thumb Crotch Length</u>
The distance from the
metacarpal-phalangeal
joint of the thumb to
the notch between the
1st and 2nd fingers.

10
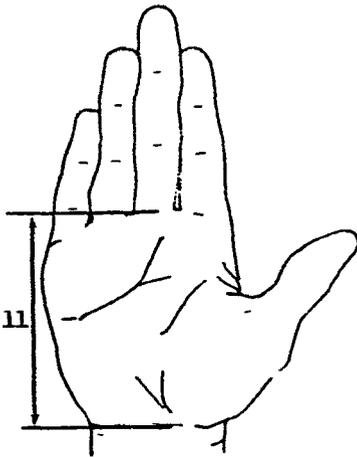
11 - <u>Palm Length</u>
The distance from the
base of the hand to the
furrow where the middle
finger folds upon the
palm.

11

12
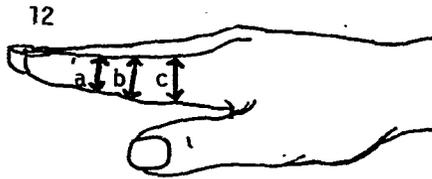
**12 - <u>Forefinger Thickness</u>**

    a. Middle of 2nd phalange
    b. 1st-2nd phalangeal joint
    c. Middle of 1st phalange

ANTHROPOMETRIC MEASUREMENT OF MAXIMUM FORCE TEST

GENDER : MALE

| SUBJECT | AGE | GRIP STRENGTH PRE. | GRIP STRENGTH POST | GRIP DIA. | HAND THICK-NESS | HAND BREADTH | HAND LENGTH | PALM LENGTH | FORE FINGER LENGTH | FIST CIR. | HAND CIR. | THUMB CROTCH LENGTH | FORE ARM CIR. | FINGER CIR. |
|---------|-----|------|------|------|-----|-----|------|------|------|------|------|-----|------|-----|
| 1 | 18 | 49 | 57 | 12.6 | 3.0 | 8.9 | 19.8 | 11.5 | 14.4 | 29.5 | 21.4 | 7.2 | 29.5 | 6.5 |
| 2 | 27 | 50 | 56 | 12.1 | 2.8 | 9.5 | 19.4 | 11.0 | 14.1 | 29.9 | 22.6 | 7.0 | 31.2 | 6.6 |
| 3 | 44 | 36 | 39 | 10.8 | 3.0 | 9.0 | 17.7 | 10.3 | 14.1 | 27.5 | 20.2 | 7.7 | 31.0 | 7.3 |
| 4 | 21 | 47 | 50 | 12.1 | 3.1 | 8.9 | 19.1 | 11.0 | 16.0 | 29.6 | 21.0 | 9.0 | 30.7 | 7.8 |
| 5 | 30 | 45 | 46 | 11.7 | 2.8 | 9.2 | 11.4 | 9.4 | 14.6 | 28.7 | 21.1 | 7.3 | 27.2 | 6.1 |
| 6 | 24 | 51 | 65 | 13.1 | 3.1 | 9.1 | 20. | 2.0 | 15.2 | 29.0 | 20.3 | 9.0 | 29.8 | 6.1 |
| 7 | 23 | 68 | 70 | 13.6 | 3.1 | 9.5 | 20.3 | 11.7 | 14.8 | 29.4 | 22.3 | 7.0 | 30.1 | 6.4 |
| 8 | 22 | 49 | 52 | 11.9 | 2.7 | 8.6 | 19.0 | 10.9 | 12.6 | 27.3 | 21.0 | 6.5 | 25.9 | .6.0 |
| 9 | 26 | 38 | 44 | 12.7 | 3.1 | 9.3 | 28.0 | 11.5 | 13.5 | 30.2 | 22.0 | 8.3 | 28.5 | 6.6 |
| 10 | 26 | 77 | 71 | 13.0 | 3.2 | 9.8 | 20.5 | 11.5 | 16.1 | 30.0 | 22.1 | 8.2 | 31.3 | 6.7 |

GENDER : FEMALE

| SUBJECT | AGE | GRIP STRENGTH PRE. | GRIP STRENGTH POST | GRIP DIA. | HAND THICK-NESS | HAND BREADTH | HAND LENGTH | PALM LENGTH | FORE FINGER LENGTH | FIST CIR. | HAND CIR. | THUMB CROTCH LENGTH | FORE ARM CIR. | FINGER CIR. |
|---------|-----|------|------|------|-----|-----|------|------|------|------|------|-----|------|-----|
| 1 | 22 | 29 | 31 | 12.1 | 2.9 | 7.9 | 18.0 | 10.0 | 13.4 | 25.4 | 19.0 | 6.2 | 23.1 | 5.5 |
| 2 | 21 | 23 | 33 | 12.2 | 2.9 | 8.5 | 13.6 | 10.5 | 14.6 | 26.5 | 19.7 | 7.2 | 26.5 | 5.9 |
| 3 | 23 | 29 | 33 | 12.3 | 2.5 | 7.9 | 17.8 | 10.1 | 13.7 | 24.3 | 19.1 | 6.0 | 27.5 | 5.8 |
| 4 | 42 | 39 | 37 | 11.3 | 3.1 | 8.2 | 18.5 | 10.0 | 14.1 | 26.9 | 20.5 | 6.8 | 27.1 | 6.2 |
| 5 | 24 | 27 | 33 | 11.8 | 3.0 | 8.7 | 19.8 | 11.0 | 15.3 | 27.9 | 19.5 | 7.6 | 27.0 | 5.9 |
| 6 | 22 | 32 | 33 | 13.6 | 2.6 | 7.9 | 18.7 | 10.6 | 14.9 | 23.9 | 18.9 | 8.0 | 24.5 | 5.3 |
| 7 | 35 | 27 | 28 | 11.4 | 2.8 | 8.9 | 17.5 | 10.0 | 13.7 | 24.7 | 18.3 | 6.8 | 28.0 | 5.4 |
| 8 | 38 | 32 | 37 | 12.1 | 2.8 | 8.3 | 18.8 | 10.5 | 14.3 | 25.5 | 18.6 | 7.5 | 25.0 | 5.4 |
| 9 | 38 | 36 | 37 | 12.7 | 2.8 | 8.3 | 18.3 | 10.9 | 13.2 | 25.7 | 19.5 | 6.8 | 27.7 | 5.4 |
| 10 | 21 | 26 | 27 | 10.2 | 2.5 | 7.8 | 17.2 | 10.3 | 14.1 | 24.2 | 17.7 | 8.0 | 23.9 | 5.2 |

ANTHROPOMETRIC MEASUREMENT OF ENDURENCE TEST

GENDER : MALE

| SUBJECT | AGE | GRIP STRENGTH PRE. | GRIP STRENGTH POST | GRIP DIA. | HAND THICK-NESS | HAND BREADTH | HAND LENGTH | PALM LENGTH | FORE FINGER LENGTH | FIST CIR. | HAND CIR. | THUMB CROTCH LENGTH | FORE ARM CIR. | 3RD FINGER CIR. | LOAD WEIGHT |
|---------|-----|------|------|------|-----|-----|------|------|------|------|------|-----|------|-----|------|
| 1 | 26 | 77 | 71 | 13.0 | 3.2 | 9.8 | 20.5 | 11.5 | 16.1 | 30.0 | 22.1 | 8.2 | 31.3 | 6.7 | 10.0 |
| 2 | 28 | 38 | 37 | 14.5 | 2.7 | 9.1 | 20.3 | 11.6 | 15.5 | 27.3 | 20.6 | 7.8 | 27.6 | 5.4 | 5.5 |
| 3 | 24 | 51 | 66 | 13.1 | 3.1 | 9.1 | 20.3 | 12.0 | 15.2 | 29.0 | 20.3 | 9.0 | 29.8 | 6.1 | 7.2 |
| 4 | 23 | 34 | 25 | 13.0 | 2.8 | 6.5 | 19.5 | 11.2 | 14.9 | 27.5 | 19.1 | 7.9 | 29.4 | 5.6 | 6.2 |
| 5 | 23 | 59 | 59 | 13.2 | 2.8 | 9.2 | 16.2 | 11.2 | 13.5 | 28.0 | 21.0 | 5.5 | 27.5 | 7.0 | 8.1 |
| 6 | 22 | 56 | 52 | 12.3 | 3.0 | 8.9 | 17.9 | 10.1 | 15.1 | 26.9 | 19.5 | 8.3 | 28.8 | 5.8 | 9.3 |
| 7 | 24 | 44 | 49 | 13.3 | 3.0 | 9.1 | 19.8 | 11.3 | 15.2 | 28.2 | 20.3 | 7.6 | 31.1 | 6.1 | 6.3 |
| 8 | 27 | 57 | 47 | 14.0 | 2.9 | 9.2 | 20.1 | 11.7 | 15.4 | 29.0 | 19.8 | 8.5 | 30.1 | 6.4 | 7.2 |
| 9 | 24 | 58 | 60 | 14.4 | 3.2 | 9.5 | 20.7 | 11.6 | 16.2 | 30.5 | 22.2 | 8.0 | 29.9 | 6.0 | 7.8 |
| 10 | 23 | 46 | 44 | 13.6 | 2.7 | 9.3 | 19.8 | 11.3 | 15.5 | 27.0 | 20.9 | 7.8 | 27.4 | 6.0 | 6.6 |

GENDER : FEMALE

| SUBJECT | AGE | GRIP STRENGTH PRE. | GRIP STRENGTH POST | GRIP DIA. | HAND THICK-NESS | HAND BREADTH | HAND LENGTH | PALM LENGTH | FORE FINGER LENGTH | FIST CIR. | HAND CIR. | THUMB CROTCH LENGTH | FORE ARM CIR. | 3RD FINGER CIR. | LOAD WEIGHT |
|---------|-----|------|------|------|-----|-----|------|------|------|------|------|-----|------|-----|------|
| 1 | 35 | 27 | 28 | 11.4 | 2.8 | 8.9 | 17.5 | 10.0 | 13.7 | 24.7 | 18.3 | 6.8 | 28.0 | 5.4 | 6.2 |
| 2 | 40 | 31 | 24 | 12.1 | 2.5 | 8.0 | 17.4 | 9.8 | 13.1 | 23.6 | 16.7 | 6.0 | 23.2 | 5.1 | 5.0 |
| 3 | 23 | 28 | 24 | 10.8 | 3.0 | 8.0 | 17.1 | 10.1 | 12.1 | 23.1 | 18.3 | 6.0 | 25.1 | 5.0 | 4.5 |
| 4 | 37 | 28 | 28 | 12.7 | 2.8 | 7.8 | 18.0 | 10.0 | 14.9 | 24.9 | 18.4 | 7.5 | 23.0 | 5.1 | 3.9 |
| 5 | 61 | 22 | 26 | 12.2 | 2.7 | 7.7 | 19.9 | 11.3 | 14.5 | 26.5 | 19.0 | 7.0 | 28.0 | 5.5 | 4.3 |
| 6 | 22 | 31 | 36 | 12.8 | 2.5 | 8.4 | 19.4 | 11.8 | 13.3 | 25.8 | 18.5 | 6.9 | 26.3 | 5.6 | 6.3 |
| 7 | 21 | 26 | 26 | 10.2 | 2.5 | 7.8 | 17.2 | 10.3 | 14.1 | 24.2 | 17.7 | 5.2 | 23.9 | 8.0 | 5.0 |
| 8 | 25 | 22 | 24 | 12.1 | 2.5 | 7.5 | 16.9 | 10.0 | 13.6 | 22.0 | 16.8 | 7.7 | 21.8 | 5.0 | 6.3 |
| 9 | 22 | 27 | 32 | 11.8 | 2.5 | 8.3 | 17.3 | 10.1 | 15.0 | 25.0 | 18.8 | 8.4 | 24.6 | 5.8 | 4.5 |
| 10 | 24 | 27 | 28 | 13.1 | 2.6 | 8.2 | 17.9 | 10.4 | 14.0 | 24.2 | 18.3 | 7.3 | 22.3 | 5.3 | 4.5 |

APPENDIX E

THRUST PUSH AND PULL DATA

GENDER : MALE    THRUST

| SUB. | SIZE | R | SHAPE C PUSH | PULL | SHAPE D PUSH | PULL | SHAPE Q PUSH | PULL | SHAPE T PUSH | PULL | SHAPE S PUSH | PULL | SHAPE W PUSH | PULL | SHAPE X PUSH | PULL | SHAPE Y PUSH | PULL | SHAPE Z PUSH | PULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 96.9 | 103.4 | 96.9 | 90.5 | 64.6 | 74.3 | 106.6 | 103.4 | 90.5 | 77.6 | 84.0 | 67.9 | 84.0 | 96.9 | 84.0 | 64.6 | 87.3 | 90.5 |
| | | 2 | 87.3 | 109.9 | 96.9 | 77.6 | 84.0 | 80.8 | 84.0 | 96.9 | 90.5 | 93.7 | 67.9 | 64.6 | 96.9 | 90.5 | 84.0 | 71.1 | 80.8 | 93.7 |
| | | 3 | 96.9 | 84.0 | 93.7 | 96.9 | 77.6 | 87.3 | 103.4 | 84.0 | 103.4 | 96.9 | 87.3 | 77.6 | 100.2 | 84.0 | 67.9 | 80.8 | | 90.5 |
| | 9 | 1 | 96.9 | 100.2 | 87.3 | 87.3 | 93.7 | 90.5 | 119.6 | 100.2 | 129.3 | 100.2 | 119.6 | 93.7 | 116.3 | 90.5 | 100.2 | 100.2 | 113.1 | 96.9 |
| | | 2 | 100.2 | 106.6 | 87.3 | 87.3 | 100.2 | 96.9 | 119.6 | 93.7 | 116.3 | 103.4 | 119.6 | 96.9 | 113.1 | 96.9 | 100.2 | 96.9 | 129.3 | 103.4 |
| | | 3 | 96.9 | 109.9 | 106.6 | 93.7 | 100.2 | 87.3 | 116.3 | 93.7 | 113.1 | 109.9 | 126.0 | 109.9 | 116.3 | 113.1 | 96.9 | 100.2 | 103.4 | 100.2 |
| | 11 | 1 | 122.8 | 100.2 | 129.3 | 109.9 | 126.0 | 103.4 | 103.4 | 109.9 | 109.9 | 100.2 | 116.3 | 109.9 | 119.6 | 113.1 | 103.4 | 119.6 | 103.4 | 103.4 |
| | | 2 | 129.3 | 103.4 | 122.8 | 103.4 | 139.0 | 109.9 | 113.1 | 109.9 | 109.9 | 109.9 | 135.7 | 106.6 | 100.2 | 106.6 | 106.6 | 113.1 | 116.3 | 103.4 |
| | | 3 | 109.9 | 96.9 | 132.5 | 113.1 | 126.0 | 113.1 | 116.3 | 113.1 | 106.6 | 119.6 | 119.6 | 116.3 | 113.1 | 109.9 | 132.5 | 113.1 | 106.6 | 116.3 |
| | 13 | 1 | 119.6 | 93.7 | 109.9 | 119.6 | 135.7 | 129.3 | 129.3 | 119.6 | 116.3 | 100.2 | 96.9 | 106.6 | 139.0 | 116.3 | 113.1 | 113.1 | 116.3 | 116.3 |
| | | 2 | 129.3 | 100.2 | 116.3 | 119.6 | 129.3 | 132.5 | 119.6 | 109.9 | 135.7 | 106.6 | 109.9 | 113.1 | 139.0 | 122.8 | 106.6 | 116.3 | 116.3 | 129.3 |
| | | 3 | 116.3 | 93.7 | 116.3 | 109.9 | 122.8 | 126.0 | 122.8 | 119.6 | 135.7 | 116.3 | 93.7 | 100.2 | 148.1 | 122.8 | 100.2 | 113.1 | 119.6 | 122.8 |
| 2 | 7 | 1 | 67.9 | 90.5 | 64.6 | 61.4 | 67.9 | 77.6 | 58.2 | 67.9 | 64.6 | 87.3 | 74.3 | 64.6 | 64.6 | 48.5 | 80.8 | 84.0 | 74.3 | 90.5 |
| | | 2 | 87.3 | 84.0 | 67.9 | 74.3 | 77.6 | 67.9 | 61.4 | 64.6 | 80.8 | 80.8 | 74.3 | 77.6 | 77.6 | 71.1 | 74.3 | 93.7 | 71.1 | 80.8 |
| | | 3 | 90.5 | 74.3 | 61.4 | 74.3 | 64.6 | 64.6 | 64.6 | 64.6 | 87.3 | 80.8 | 74.3 | 80.8 | 71.1 | 58.2 | 103.4 | 84.0 | 71.1 | 80.8 |
| | 9 | 1 | 77.6 | 80.8 | 100.2 | 87.3 | 96.9 | 87.3 | 106.6 | 103.4 | 93.7 | 87.3 | 84.0 | 84.0 | 84.0 | 90.5 | 71.1 | 113.1 | 100.2 | 103.4 |
| | | 2 | 84.0 | 93.7 | 84.0 | 80.8 | 113.1 | 96.9 | 113.1 | 106.6 | 96.9 | 93.7 | 84.0 | 100.2 | 100.2 | 71.1 | 74.3 | 93.7 | 96.9 | 100.2 |
| | | 3 | 80.8 | 84.0 | 96.9 | 87.3 | 106.6 | 96.9 | 109.9 | 109.9 | 103.4 | 80.8 | 106.6 | 90.5 | 90.5 | 84.0 | 90.5 | 84.0 | 96.9 | 103.4 |
| | 11 | 1 | 93.7 | 116.3 | 96.9 | 103.4 | 100.2 | 90.5 | 116.3 | 126.0 | 103.2 | 80.8 | 93.7 | 103.4 | 100.2 | 80.8 | 87.3 | 93.7 | 116.3 | 116.3 |
| | | 2 | 106.6 | 93.7 | 96.9 | 103.4 | 106.6 | 84.0 | 116.3 | 113.1 | 100.2 | 90.5 | 103.4 | 90.5 | 103.4 | 80.8 | 80.8 | 106.6 | 109.9 | 113.1 |
| | | 3 | 103.4 | 109.9 | 109.9 | 109.9 | 90.5 | 103.4 | 116.3 | 116.3 | 103.4 | 100.2 | 109.2 | 103.4 | 90.5 | 90.5 | 90.5 | 96.9 | 116.3 | 109.9 |
| | 13 | 1 | 74.3 | 93.7 | 113.1 | 106.6 | 126.0 | 122.8 | 116.3 | 116.3 | 116.3 | 74.3 | 77.6 | 96.9 | 135.7 | 119.6 | 116.3 | 106.6 | 100.2 | 119.6 |
| | | 2 | 90.5 | 74.3 | 116.3 | 106.6 | 119.6 | 106.6 | 116.3 | 126.0 | 109.9 | 80.8 | 80.8 | 84.0 | 122.8 | 113.1 | 109.9 | 103.4 | 113.1 | 113.1 |
| | | 3 | 90.5 | 93.7 | 103.4 | 113.1 | 116.3 | 116.3 | 116.3 | 116.3 | 90.9 | 80.8 | 80.8 | 100.2 | 119.6 | 113.1 | 96.9 | 90.5 | | 113.1 |
| 3 | 7 | 1 | 93.7 | 87.3 | 84.0 | 100.2 | 96.9 | 87.3 | 74.3 | 103.4 | 80.8 | 87.3 | 142.2 | 84.0 | 100.2 | 96.9 | 74.3 | 87.3 | 100.2 | 106.6 |
| | | 2 | 84.0 | 84.0 | 103.4 | 90.5 | 96.9 | 93.7 | 100.2 | 96.9 | 74.3 | 90.5 | 96.9 | 84.0 | 109.9 | 90.5 | 77.6 | 90.5 | 100.2 | 100.2 |
| | | 3 | 90.5 | 84.0 | 96.9 | 100.2 | 109.9 | 100.2 | 93.7 | 93.7 | 61.4 | 96.9 | 93.7 | 87.3 | 84.0 | 84.0 | 100.2 | 93.7 | 90.5 | 93.7 |
| | 9 | 1 | 96.9 | 103.4 | 77.6 | 93.7 | 77.6 | 100.2 | 93.7 | 106.6 | 106.6 | 84.0 | 119.6 | 109.9 | 100.2 | 100.2 | 96.9 | 113.1 | 119.6 | 116.3 |
| | | 2 | 106.6 | 93.7 | 106.6 | 100.2 | 103.4 | 93.7 | 90.5 | 103.4 | 90.5 | 77.6 | 122.8 | 103.4 | 100.2 | 93.7 | 109.9 | 96.9 | 116.3 | 113.1 |
| | | 3 | 122.8 | 113.1 | 106.6 | 103.4 | 87.3 | 93.7 | 106.6 | 113.1 | 80.8 | 100.2 | 122.8 | 116.3 | 109.9 | 90.5 | 100.2 | 96.9 | 116.3 | 109.9 |
| | 11 | 1 | 100.2 | 116.3 | 106.6 | 113.1 | 100.2 | 103.4 | 100.2 | 103.4 | 109.9 | 113.1 | 109.9 | 113.1 | 109.9 | 113.1 | 116.3 | 113.1 | 122.8 | 113.1 |
| | | 2 | 116.3 | 109.9 | 103.4 | 109.9 | 106.6 | 90.5 | 96.9 | 93.7 | 119.6 | 100.2 | 103.4 | 122.8 | 119.6 | 119.6 | 109.9 | 103.4 | 129.3 | 106.6 |
| | | 3 | 132.5 | 116.3 | 106.6 | 103.4 | 96.9 | 93.7 | 109.9 | 100.2 | 109.9 | 113.1 | 113.1 | 116.3 | 129.3 | 129.3 | 109.9 | 109.2 | | 119.6 |
| | 13 | 1 | 106.6 | 90.5 | 96.9 | 109.9 | 90.5 | 93.7 | 96.9 | 109.9 | 100.2 | 93.7 | 119.6 | 113.1 | 132.5 | 113.1 | 122.8 | 119.6 | 139.0 | 119.6 |
| | | 2 | 93.7 | 103.4 | 109.9 | 109.9 | 100.2 | 93.7 | 103.4 | 100.2 | 87.3 | 87.3 | 119.6 | 113.1 | 129.3 | 116.3 | 126.0 | 109.9 | 113.1 | 126.0 |
| | | 3 | 103.4 | 106.6 | 113.1 | 109.9 | 100.2 | 103.4 | 126.0 | 116.3 | 100.2 | 90.5 | 145.4 | 119.6 | 122.8 | 119.6 | 122.8 | 119.6 | 113.1 | 125.1 |
| 4 | 7 | 1 | 71.1 | 54.9 | 61.4 | 74.3 | 87.3 | 93.7 | 77.6 | 67.9 | 67.9 | 61.4 | 113.1 | 109.9 | 90.5 | 96.9 | 67.9 | 74.3 | 80.8 | 84.0 |
| | | 2 | 77.6 | 77.6 | 74.3 | 77.6 | 84.0 | 87.3 | 74.3 | 90.5 | 71.1 | 74.3 | 116.3 | 106.6 | 87.3 | 87.3 | 74.3 | 80.8 | 84.0 | 93.7 |
| | | 3 | 84.0 | 77.6 | 74.3 | 77.6 | 96.9 | 80.8 | 71.1 | 77.6 | 74.3 | 80.8 | 119.6 | 119.6 | 77.6 | 90.5 | 74.3 | 90.5 | 77.6 | 96.9 |
| | 9 | 1 | 58.2 | 54.9 | 90.5 | 90.5 | 109.9 | 96.9 | 184.2 | 106.6 | 74.3 | 74.3 | 77.6 | 77.6 | 64.6 | 77.6 | 64.6 | 77.6 | 119.6 | 116.3 |
| | | 2 | 61.4 | 67.9 | 96.9 | 90.5 | 109.9 | 106.6 | 177.7 | 96.9 | 84.0 | 84.0 | 80.8 | 77.6 | 74.3 | 71.1 | 64.6 | 74.3 | 116.3 | 109.9 |
| | | 3 | 67.9 | 64.6 | 100.2 | 84.5 | 100.2 | 90.5 | 193.9 | 103.4 | 80.8 | 80.5 | 77.6 | 84.0 | 74.3 | 61.4 | 71.1 | 80.8 | 106.6 | 116.3 |
| | 11 | 1 | 71.1 | 74.3 | 90.5 | 93.7 | 74.3 | 74.3 | 119.6 | 103.4 | 54.9 | 80.8 | 116.3 | 106.6 | 87.3 | 80.8 | 74.3 | 74.3 | 67.9 | 74.3 |
| | | 2 | 77.6 | 80.8 | 90.5 | 90.5 | 74.3 | 90.5 | 113.1 | 100.2 | 74.3 | 87.3 | 113.1 | 93.7 | 90.5 | 80.8 | 74.3 | 74.3 | 74.3 | 74.3 |
| | | 3 | 84.0 | 80.8 | 93.7 | 90.5 | 71.1 | 84.0 | 106.6 | 109.9 | 67.9 | 93.7 | 109.9 | 87.3 | 93.7 | 87.3 | 67.9 | 77.6 | 67.9 | 74.3 |
| | 13 | 1 | 67.9 | 67.9 | 90.5 | 106.6 | 122.8 | 93.7 | 96.9 | 109.9 | 74.3 | 84.0 | 87.3 | 61.4 | 77.6 | 74.3 | 80.8 | 74.3 | 71.1 | 71.1 |
| | | 2 | 64.6 | 61.4 | 116.3 | 100.2 | 129.3 | 103.4 | 96.9 | 100.2 | 74.3 | 80.8 | 90.5 | 71.1 | 77.6 | 87.3 | 74.3 | 74.3 | 74.3 | 74.3 |
| | | 3 | 74.3 | 74.3 | 106.6 | 106.6 | 132.5 | 103.4 | 96.9 | 84.0 | 77.6 | 77.6 | 84.0 | 77.6 | 77.6 | 77.6 | 74.3 | 87.3 | 71.1 | 74.3 |
| 5 | 7 | 1 | 90.5 | 93.7 | 77.6 | 74.3 | 74.3 | 90.5 | 103.4 | 90.5 | 80.8 | 77.6 | 90.5 | 87.3 | 80.8 | 84.0 | 71.1 | 67.9 | 80.8 | 84.0 |
| | | 2 | 87.3 | 74.3 | 90.5 | 93.7 | 87.3 | 74.3 | 100.2 | 93.7 | 87.3 | 84.0 | 96.9 | 103.4 | 80.8 | 93.7 | 74.3 | 80.8 | 87.3 | 93.7 |
| | | 3 | 87.3 | 87.3 | 84.0 | 84.0 | 77.6 | 74.3 | 106.6 | 84.0 | 90.5 | 77.6 | 103.4 | 90.5 | 90.5 | 90.5 | 64.6 | 74.3 | 87.3 | 87.3 |
| | 9 | 1 | 96.9 | 96.9 | 90.5 | 50.5 | 116.3 | 116.3 | 116.3 | 113.1 | 96.9 | 84.0 | 93.7 | 103.4 | 93.7 | 109.9 | 100.2 | 106.6 | 113.1 | 96.9 |
| | | 2 | 106.6 | 93.7 | 100.2 | 96.9 | 116.3 | 109.9 | 116.3 | 122.8 | 96.9 | 103.4 | 90.5 | 100.2 | 93.7 | 103.4 | 109.9 | 109.9 | 90.5 | 93.7 |
| | | 3 | 113.1 | 96.9 | 93.7 | 100.2 | 116.3 | 122.8 | 115.7 | 109.9 | 71.1 | 109.9 | 96.9 | 90.5 | 100.2 | 100.2 | 96.9 | 96.9 | 87.3 | 96.9 |
| | 11 | 1 | 116.3 | 100.2 | 126.0 | 116.3 | 116.3 | 100.2 | 113.1 | 113.1 | 122.8 | 103.4 | 87.3 | 103.4 | 109.9 | 106.6 | 109.9 | 106.6 | 113.1 | 96.9 |
| | | 2 | 106.6 | 90.5 | 122.8 | 106.6 | 116.3 | 116.3 | 100.2 | 113.1 | 106.6 | 122.8 | 100.2 | 100.2 | 119.6 | 113.1 | 135.7 | 113.1 | 119.6 | 103.4 |
| | | 3 | 109.9 | 100.2 | 126.0 | 116.3 | 119.6 | 113.1 | 109.9 | 116.3 | 109.9 | 116.3 | 93.7 | 113.1 | 129.3 | 113.1 | 116.3 | 113.1 | 116.3 | 103.4 |
| | 13 | 1 | 116.3 | 96.9 | 109.9 | 93.7 | 122.8 | 109.9 | 132.5 | 116.3 | 116.3 | 103.4 | 116.3 | 109.9 | 113.1 | 113.1 | 132.5 | 122.8 | 126.0 | 106.6 |
| | | 2 | 106.6 | 90.5 | 103.4 | 100.2 | 100.2 | 106.6 | 129.3 | 119.6 | 135.7 | 100.2 | 109.9 | 116.3 | 109.9 | 106.6 | 116.3 | 100.2 | 113.1 | 109.9 |
| | | 3 | 113.1 | 103.4 | 100.2 | 87.3 | 100.2 | 109.9 | 129.3 | 119.6 | 119.6 | 96.9 | 109.9 | 113.1 | 122.8 | 113.1 | 126.0 | 109.9 | 116.3 | 116.3 |

(TO BE CONTINUED)

GENDER : MALE   THRUST   (CONTINUED)

SHAPE C PUSH PULL | SHAPE D PUSH PULL | SHAPE Q PUSH PULL | SHAPE T PUSH PULL | SHAPE S PUSH PULL | SHAPE W PUSH PULL | SHAPE X PUSH PULL | SHAPE Y PUSH PULL | SHAPE Z PUSH PULL

SUB. SIZE   R

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| SUB. | SIZE | R | SHAPE C PUSH | PULL | SHAPE D PUSH | PULL | SHAPE O PUSH | PULL | SHAPE T PUSH | PULL | SHAPE S PUSH | PULL | SHAPE W PUSH | PULL | SHAPE X PUSH | PULL | SHAPE Y PUSH | PULL | SHAPE Z PUSH | PULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 48.5 | 48.5 | 58.2 | 64.6 | 54.9 | 58.2 | 51.7 | 58.2 | 48.5 | 45.2 | 61.4 | 61.4 | 67.9 | 64.6 | 48.5 | 51.7 | 51.7 | 58.2 |
|  |  | 2 | 58.2 | 51.7 | 54.9 | 67.9 | 64.6 | 54.9 | 51.7 | 58.2 | 45.2 | 42.0 | 71.1 | 58.2 | 58.2 | 64.6 | 45.2 | 54.9 | 51.7 | 54.9 |
|  |  | 3 | 45.2 | 51.7 | 58.2 | 64.6 | 51.7 | 64.6 | 45.2 | 54.2 | 45.2 | 45.2 | 64.6 | 58.2 | 64.6 | 67.9 | 58.2 | 64.6 | 48.5 | 54.9 |
|  | 9 | 1 | 64.6 | 58.2 | 58.2 | 54.9 | 61.4 | 61.4 | 64.6 | 61.4 | 64.6 | 64.6 | 54.9 | 48.5 | 61.4 | 64.6 | 58.2 | 61.4 | 64.6 | 61.4 |
|  |  | 2 | 58.2 | 58.2 | 54.9 | 54.9 | 61.4 | 58.2 | 58.2 | 64.6 | 64.6 | 61.4 | 51.7 | 54.9 | 64.6 | 58.2 | 54.9 | 54.9 | 71.1 | 64.6 |
|  |  | 3 | 61.4 | 58.2 | 58.2 | 58.2 | 64.6 | 61.4 | 61.4 | 64.6 | 61.4 | 58.2 | 54.9 | 58.2 | 58.2 | 58.2 | 54.9 | 58.2 | 64.6 | 61.4 |
|  | 11 | 1 | 54.9 | 54.9 | 58.2 | 51.7 | 61.9 | 64.6 | 61.9 | 67.9 | 58.2 | 54.9 | 61.4 | 54.9 | 64.6 | 64.6 | 64.6 | 71.1 | 61.4 | 61.4 |
|  |  | 2 | 51.7 | 64.6 | 58.2 | 58.2 | 51.7 | 58.2 | 64.6 | 61.4 | 64.6 | 61.4 | 64.6 | 54.9 | 64.6 | 64.6 | 67.9 | 58.2 | 67.9 | 64.6 |
|  |  | 3 | 58.2 | 54.9 | 61.4 | 51.7 | 54.9 | 58.2 | 64.6 | 54.9 | 61.4 | 58.2 | 67.9 | 54.9 | 64.9 | 61.4 | 71.1 | 54.9 | 64.6 | 61.4 |
|  | 13 | 1 | 51.7 | 64.6 | 64.6 | 51.7 | 58.2 | 67.9 | 45.2 | 45.2 | 58.2 | 61.4 | 54.9 | 51.7 | 51.7 | 54.9 | 54.9 | 48.5 | 71.1 | 67.9 |
|  |  | 2 | 58.2 | 64.6 | 61.4 | 51.7 | 64.6 | 67.9 | 54.9 | 48.5 | 64.6 | 64.6 | 61.4 | 51.7 | 51.7 | 54.9 | 51.7 | 45.2 | 67.9 | 67.9 |
|  |  | 3 | 61.4 | 67.9 | 61.4 | 51.7 | 64.6 | 71.1 | 45.2 | 42.2 | 61.4 | 64.6 | 58.2 | 48.5 | 54.9 | 54.9 | 58.2 | 45.2 | 67.9 | 61.4 |
| 2 | 7 | 1 | 61.4 | 67.9 | 51.7 | 64.6 | 64.6 | 61.4 | 48.5 | 54.9 | 71.1 | 58.2 | 51.7 | 61.4 | 48.5 | 64.6 | 58.2 | 48.5 | 48.5 | 64.6 |
|  |  | 2 | 64.6 | 64.6 | 48.5 | 61.4 | 58.2 | 64.6 | 54.9 | 61.4 | 74.3 | 64.6 | 58.2 | 51.7 | 45.2 | 71.1 | 48.5 | 54.9 | 45.2 | 54.9 |
|  |  | 3 | 67.9 | 64.6 | 51.7 | 64.6 | 61.4 | 48.5 | 58.2 | 58.2 | 64.6 | 64.3 | 45.2 | 64.6 | 58.2 | 58.2 | 51.7 | 48.5 | 51.7 | 61.4 |
|  | 9 | 1 | 45.2 | 67.9 | 64.6 | 64.6 | 74.3 | 74.3 | 84.0 | 77.6 | 54.9 | 74.3 | 67.9 | 87.3 | 74.3 | 71.1 | 64.6 | 61.4 | 74.3 | 77.6 |
|  |  | 2 | 64.6 | 67.9 | 64.6 | 64.6 | 58.2 | 64.6 | 74.3 | 74.3 | 64.6 | 67.9 | 58.2 | 71.1 | 64.6 | 71.1 | 67.9 | 61.4 | 71.1 | 87.3 |
|  |  | 3 | 71.1 | 67.9 | 54.9 | 58.2 | 71.1 | 77.6 | 67.9 | 74.3 | 77.6 | 64.6 | 64.6 | 77.6 | 74.3 | 61.9 | 58.2 | 64.6 | 84.0 | 80.8 |
|  | 11 | 1 | 67.9 | 74.3 | 61.4 | 77.6 | 74.3 | 77.6 | 67.9 | 71.1 | 54.9 | 80.8 | 74.3 | 71.1 | 64.6 | 74.3 | 64.6 | 87.3 | 74.3 | 77.6 |
|  |  | 2 | 74.3 | 64.6 | 71.1 | 64.6 | 71.6 | 77.6 | 74.3 | 67.9 | 48.5 | 71.1 | 64.6 | 71.1 | 67.9 | 71.1 | 74.3 | 71.1 | 74.3 | 74.3 |
|  | 13 | 1 | 51.7 | 71.1 | 61.4 | 74.3 | 71.1 | 64.6 | 74.3 | 77.6 | 61.4 | 51.7 | 74.3 | 74.3 | 74.3 | 84.0 | 64.6 | 74.3 | 87.3 | 87.3 |
|  |  | 2 | 61.4 | 67.9 | 74.3 | 71.1 | 71.1 | 64.6 | 80.8 | 84.0 | 54.9 | 61.4 | 67.9 | 74.3 | 67.9 | 74.3 | 74.3 | 71.1 | 74.3 | 80.8 |
|  |  | 3 | 64.6 | 67.9 | 67.9 | 67.9 | 61.4 | 58.2 | 74.3 | 84.0 | 58.2 | 48.5 | 71.1 | 71.1 | 77.6 | 71.6 | 67.9 | 74.3 | 74.3 | 74.3 |
| 3 | 7 | 1 | 45.2 | 54.9 | 58.2 | 54.9 | 48.5 | 58.2 | 58.2 | 51.7 | 61.4 | 58.2 | 48.5 | 61.4 | 38.8 | 38.8 | 35.5 | 61.4 | 45.2 | 51.7 |
|  |  | 2 | 51.7 | 64.6 | 61.4 | 64.6 | 61.4 | 58.2 | 48.5 | 51.7 | 71.1 | 54.9 | 67.9 | 64.6 | 48.5 | 61.4 | 45.2 | 48.5 | 45.2 | 51.7 |
|  |  | 3 | 58.2 | 64.6 | 54.9 | 64.6 | 61.4 | 42.0 | 54.9 | 48.5 | 74.3 | 58.2 | 61.4 | 67.9 | 45.2 | 61.4 | 54.9 | 48.5 | 58.2 | 58.2 |
|  | 9 | 1 | 58.2 | 71.1 | 38.8 | 71.1 | 58.2 | 74.3 | 67.9 | 80.8 | 48.5 | 61.4 | 84.0 | 58.2 | 54.9 | 71.1 | 58.2 | 64.6 | 71.1 | 64.6 |
|  |  | 2 | 61.4 | 67.9 | 42.0 | 74.3 | 64.6 | 71.1 | 67.9 | 74.3 | 64.6 | 71.1 | 77.6 | 58.2 | 61.4 | 61.4 | 61.4 | 58.2 | 71.1 | 54.9 |
|  |  | 3 | 58.2 | 71.1 | 67.9 | 71.1 | 64.6 | 58.2 | 74.3 | 71.1 | 58.2 | 64.6 | 77.6 | 71.1 | 58.2 | 64.6 | 64.6 | 64.6 | 51.7 | 64.6 |
|  | 11 | 1 | 58.2 | 51.7 | 51.7 | 71.1 | 74.3 | 74.3 | 38.8 | 58.2 | 51.7 | 74.3 | 71.1 | 67.9 | 48.5 | 51.7 | 74.3 | 84.0 | 54.9 | 48.5 |
|  |  | 2 | 48.5 | 61.4 | 61.4 | 74.3 | 71.1 | 67.9 | 58.2 | 64.6 | 64.6 | 74.3 | 74.3 | 67.9 | 58.2 | 64.6 | 77.6 | 74.3 | 58.2 | 58.2 |
|  |  | 3 | 54.9 | 67.9 | 54.9 | 71.1 | 79.3 | 80.8 | 51.7 | 67.9 | 64.6 | 74.3 | 74.3 | 64.6 | 64.6 | 67.9 | 74.3 | 90.5 | 54.9 | 61.4 |
|  | 13 | 1 | 48.5 | 61.4 | 94.0 | 71.1 | 84.0 | 84.0 | 90.5 | 71.1 | 35.5 | 64.6 | 71.1 | 80.8 | 61.4 | 74.3 | 77.6 | 71.1 | 42.0 | 64.6 |
|  |  | 2 | 51.7 | 58.2 | 71.1 | 77.6 | 84.0 | 87.3 | 64.6 | 74.3 | 42.0 | 71.1 | 64.6 | 74.3 | 64.6 | 74.3 | 74.3 | 74.3 | 67.9 | 74.3 |
|  |  | 3 | 58.2 | 74.3 | 80.8 | 74.3 | 84.0 | 84.0 | 84.0 | 67.9 | 51.7 | 67.9 | 67.9 | 74.3 | 61.4 | 74.3 | 74.3 | 64.6 | 54.9 | 64.6 |
| 4 | 7 | 1 | 61.4 | 74.3 | 74.3 | 67.9 | 51.7 | 71.1 | 74.3 | 74.3 | 71.1 | 80.8 | 51.7 | 74.3 | 58.2 | 64.6 | 93.7 | 64.6 | 74.3 | 74.3 |
|  |  | 2 | 77.6 | 71.1 | 74.3 | 100.9 | 61.4 | 74.3 | 58.2 | 77.6 | 61.4 | 74.3 | 58.2 | 64.6 | 54.9 | 67.9 | 51.7 | 61.4 | 74.3 | 96.9 |
|  |  | 3 | 74.3 | 71.1 | 74.3 | 90.5 | 58.2 | 74.3 | 64.6 | 84.0 | 64.6 | 80.8 | 64.6 | 71.1 | 51.7 | 90.5 | 61.4 | 64.6 | 87.3 | 80.8 |
|  | 9 | 1 | 61.4 | 74.1 | 74.3 | 80.8 | 74.3 | 74.3 | 71.1 | 74.3 | 74.3 | 84.0 | 93.7 | 74.3 | 67.9 | 67.9 | 74.3 | 96.9 | 71.1 | 77.6 |
|  |  | 2 | 67.9 | 74.3 | 74.3 | 87.3 | 77.6 | 74.3 | 71.1 | 77.6 | 74.3 | 77.6 | 74.3 | 84.0 | 64.6 | 74.3 | 74.3 | 80.8 | 74.3 | 77.6 |
|  |  | 3 | 67.9 | 71.1 | 84.0 | 77.0 | 71.1 | 74.3 | 74.3 | 90.5 | 74.3 | 84.0 | 64.6 | 71.1 | 71.1 | 74.3 | 77.6 | 93.7 | 71.1 | 84.0 |
|  | 11 | 1 | 93.7 | 77.6 | 67.9 | 74.3 | 96.9 | 90.9 | 74.3 | 87.3 | 74.3 | 74.6 | 84.0 | 71.1 | 67.9 | 71.1 | 67.9 | 77.6 | 61.4 | 77.6 |
|  |  | 2 | 74.3 | 77.6 | 67.9 | 74.3 | 93.7 | 100.2 | 74.3 | 87.3 | 77.6 | 84.0 | 71.1 | 74.3 | 67.9 | 87.3 | 74.3 | 90.5 | 67.9 | 77.6 |
|  |  | 3 | 71.1 | 74.3 | 71.1 | 80.8 | 100.2 | 100.2 | 71.1 | 87.3 | 71.1 | 90.5 | 64.6 | 77.6 | 67.9 | 90.5 | 74.3 | 93.7 | 74.3 | 77.6 |
|  | 13 | 1 | 64.6 | 74.3 | 58.2 | 64.6 | 61.4 | 74.3 | 71.1 | 87.3 | 67.9 | 77.6 | 61.4 | 74.3 | 64.6 | 87.3 | 67.9 | 74.3 | 74.3 | 90.5 |
|  |  | 2 | 67.9 | 71.1 | 64.6 | 80.8 | 74.3 | 80.8 | 67.9 | 87.3 | 74.3 | 80.8 | 64.6 | 80.8 | 74.3 | 84.0 | 64.6 | 77.6 | 61.4 | 87.3 |
|  |  | 3 | 64.6 | 71.1 | 80.8 | 74.3 | 74.3 | 80.8 | 71.1 | 93.7 | 74.3 | 87.3 | 71.1 | 90.5 | 71.1 | 90.5 | 67.9 | 84.0 | 67.9 | 103.4 |
| 5 | 7 | 1 | 64.6 | 67.9 | 74.3 | 71.1 | 45.2 | 64.6 | 64.6 | 67.9 | 48.5 | 58.2 | 51.7 | 64.6 | 58.2 | 74.3 | 42.0 | 54.9 | 51.7 | 64.6 |
|  |  | 2 | 67.9 | 61.4 | 67.9 | 74.3 | 48.5 | 58.2 | 54.9 | 58.2 | 48.5 | 54.9 | 71.1 | 58.2 | 51.7 | 67.9 | 35.5 | 42.0 | 54.9 | 58.2 |
|  |  | 3 | 58.2 | 80.8 | 84.0 | 64.6 | 64.6 | 64.6 | 67.9 | 48.5 | 54.9 | 54.9 | 58.2 | 64.6 | 58.2 | 58.2 | 48.5 | 48.5 | 58.2 | 64.6 |
|  | 9 | 1 | 67.9 | 64.6 | 74.3 | 67.9 | 71.1 | 74.3 | 64.6 | 71.1 | 48.5 | 74.3 | 67.9 | 64.6 | 64.6 | 71.1 | 64.6 | 93.7 | 74.3 | 67.9 |
|  |  | 2 | 64.6 | 74.3 | 90.5 | 74.3 | 71.1 | 71.1 | 51.7 | 74.3 | 74.3 | 74.3 | 64.6 | 77.6 | 77.6 | 71.1 | 64.6 | 74.3 | 74.3 | 67.9 |
|  |  | 3 | 84.0 | 71.1 | 74.3 | 64.6 | 61.4 | 84.0 | 58.2 | 84.0 | 64.6 | 74.3 | 74.3 | 77.6 | 74.3 | 71.1 | 74.3 | 84.0 | 74.3 | 74.3 |
|  | 11 | 1 | 58.2 | 96.9 | 54.9 | 61.4 | 51.7 | 67.9 | 67.9 | 74.3 | 64.6 | 64.6 | 61.4 | 71.1 | 64.6 | 74.3 | 51.7 | 74.3 | 74.3 | 74.3 |
|  |  | 2 | 64.6 | 87.3 | 48.5 | 61.4 | 74.3 | 74.3 | 77.6 | 74.3 | 64.6 | 64.6 | 74.3 | 71.1 | 71.1 | 74.3 | 58.2 | 61.4 | 84.0 | 74.3 |
|  |  | 3 | 64.6 | 84.0 | 51.7 | 74.3 | 51.7 | 71.1 | 77.6 | 77.6 | 67.9 | 74.3 | 67.9 | 67.9 | 74.3 | 74.3 | 48.5 | 87.3 | 67.9 | 93.7 |
|  | 13 | 1 | 58.2 | 74.3 | 58.2 | 61.4 | 74.3 | 74.3 | 54.9 | 67.9 | 58.2 | 87.3 | 51.7 | 61.4 | 74.3 | 74.3 | 67.9 | 74.3 | 67.9 | 64.6 |
|  |  | 2 | 74.3 | 54.9 | 67.9 | 67.9 | 67.9 | 74.3 | 64.6 | 74.3 | 61.4 | 61.4 | 54.9 | 64.6 | 67.9 | 71.1 | 74.3 | 74.3 | 64.6 | 80.8 |
|  |  | 3 | 77.6 | 71.1 | 58.2 | 67.9 | 61.4 | 90.5 | 61.4 | 64.6 | 64.6 | 61.4 | 51.7 | 61.4 | 71.1 | 84.0 | 84.0 | 67.9 | 64.6 | 74.3 |

(TO BE CONTINUED)

| SUB. | SIZE | R | SHAPE C PUSH | PULL | SHAPE D PUSH | PULL | SHAPE Q PUSH | PULL | SHAPE T PUSH | PULL | SHAPE S PUSH | PULL | SHAPE W PUSH | PULL | SHAPE X PUSH | PULL | SHAPE Y PUSH | PULL | SHAPE Z PUSH | PULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 1 | 30.8 | 48.5 | 51.7 | 67.9 | 45.2 | 58.2 | 48.5 | 58.2 | 54.9 | 54.9 | 48.5 | 48.5 | 45.2 | 51.7 | 35.5 | 54.9 | 51.7 | 51.7 |
|  |  | 2 | 42.0 | 42.0 | 48.5 | 71.1 | 42.0 | 51.7 | 48.5 | 51.7 | 51.7 | 51.7 | 42.0 | 51.7 | 45.2 | 48.5 | 38.8 | 42.0 | 51.7 | 42.0 |
|  |  | 3 | 30.5 | 42.0 | 51.7 | 58.2 | 30.8 | 45.2 | 45.2 | 45.2 | 51.7 | 58.2 | 45.2 | 51.7 | 45.2 | 51.7 | 35.5 | 42.0 | 42.0 | 48.5 |
|  | 9 | 1 | 61.4 | 67.9 | 71.1 | 48.5 | 71.1 | 58.2 | 64.6 | 64.6 | 71.1 | 48.5 | 58.2 | 54.9 | 58.2 | 67.9 | 61.4 | 54.9 | 74.3 | 61.4 |
|  |  | 2 | 74.3 | 77.6 | 45.3 | 45.2 | 67.9 | 58.2 | 58.2 | 64.6 | 64.6 | 58.2 | 61.4 | 54.9 | 54.9 | 51.7 | 54.9 | 51.7 | 61.4 | 54.9 |
|  |  | 3 | 61.4 | 74.3 | 64.6 | 51.7 | 58.2 | 54.9 | 61.4 | 71.1 | 58.2 | 67.9 | 48.5 | 67.9 | 61.4 | 54.9 | 64.6 | 67.9 | 61.4 | 58.2 |
|  | 11 | 1 | 58.2 | 67.9 | 54.9 | 64.6 | 71.1 | 58.2 | 64.6 | 58.2 | 58.2 | 51.7 | 71.1 | 71.1 | 51.7 | 51.7 | 64.6 | 67.9 | 58.2 | 58.2 |
|  |  | 2 | 51.7 | 61.4 | 58.2 | 48.5 | 58.2 | 61.4 | 58.2 | 64.6 | 48.5 | 51.7 | 61.4 | 54.9 | 51.7 | 51.7 | 61.4 | 54.9 | 51.7 | 64.6 |
|  |  | 3 | 54.9 | 61.4 | 58.2 | 58.2 | 58.2 | 54.9 | 51.7 | 74.3 | 48.5 | 58.2 | 58.2 | 71.1 | 54.9 | 48.5 | 51.7 | 58.2 | 51.7 | 67.9 |
|  | 13 | 1 | 58.2 | 54.9 | 54.9 | 54.9 | 58.6 | 80.8 | 51.7 | 51.7 | 54.9 | 54.9 | 71.1 | 77.6 | 58.2 | 54.9 | 58.2 | 64.6 | 51.7 | 51.7 |
|  |  | 2 | 51.7 | 54.9 | 58.2 | 61.4 | 58.2 | 74.3 | 45.2 | 51.7 | 61.4 | 58.2 | 58.2 | 64.6 | 58.2 | 61.4 | 54.9 | 58.2 | 51.7 | 80.8 |
|  |  | 3 | 58.2 | 54.9 | 58.2 | 51.7 | 64.6 | 74.3 | 45.2 | 51.7 | 54.9 | 51.7 | 58.2 | 32.3 | 58.2 | 61.4 | 54.9 | 64.6 | 61.4 | 58.2 |
| 7 | 7 | 1 | 64.6 | 71.1 | 54.9 | 74.3 | 64.6 | 64.6 | 48.5 | 64.6 | 64.6 | 67.9 | 74.3 | 84.0 | 64.6 | 67.9 | 64.6 | 67.9 | 61.4 | 64.6 |
|  |  | 2 | 67.9 | 84.0 | 54.9 | 74.3 | 71.1 | 74.3 | 51.7 | 64.6 | 54.9 | 48.5 | 74.3 | 64.6 | 64.6 | 71.1 | 67.9 | 61.4 | 58.2 | 77.6 |
|  |  | 3 | 64.6 | 80.8 | 58.2 | 67.9 | 71.1 | 80.8 | 58.2 | 54.9 | 58.2 | 54.9 | 58.2 | 84.0 | 74.3 | 61.4 | 74.3 | 54.9 | 54.9 | 80.8 |
|  | 9 | 1 | 58.2 | 74.3 | 58.2 | 67.9 | 74.3 | 67.9 | 74.3 | 67.9 | 71.1 | 74.3 | 64.6 | 74.3 | 61.4 | 71.1 | 80.8 | 71.1 | 64.6 | 77.6 |
|  |  | 2 | 51.7 | 61.4 | 61.4 | 74.3 | 74.3 | 74.3 | 74.3 | 96.9 | 71.1 | 77.6 | 61.4 | 77.6 | 67.9 | 67.9 | 77.6 | 77.6 | 74.3 | 84.0 |
|  |  | 3 | 64.6 | 67.9 | 71.1 | 77.6 | 77.6 | 71.1 | 64.6 | 74.3 | 80.8 | 71.1 | 87.3 | 71.1 | 67.9 | 77.6 | 80.8 | 60.8 | 71.1 | 93.7 |
|  | 11 | 1 | 74.3 | 87.3 | 77.6 | 77.6 | 77.6 | 77.6 | 64.6 | 80.8 | 71.1 | 74.3 | 77.6 | 90.5 | 74.3 | 74.3 | 58.2 | 74.3 | 64.6 | 84.0 |
|  |  | 2 | 77.6 | 74.3 | 74.3 | 71.1 | 80.8 | 90.5 | 67.9 | 74.3 | 71.1 | 77.6 | 77.6 | 84.0 | 71.1 | 74.3 | 64.6 | 74.3 | 74.3 | 84.0 |
|  |  | 3 | 84.0 | 74.3 | 74.3 | 58.5 | 74.3 | 87.3 | 71.1 | 74.3 | 74.3 | 71.1 | 90.5 | 96.9 | 87.3 | 74.3 | 77.6 | 80.8 | 74.3 | 90.5 |
|  | 13 | 1 | 67.9 | 61.4 | 64.6 | 80.8 | 71.1 | 74.3 | 71.1 | 80.8 | 67.9 | 80.8 | 71.1 | 80.8 | 61.4 | 80.8 | 61.4 | 71.1 | 80.8 | 84.0 |
|  |  | 2 | 67.9 | 61.4 | 64.6 | 80.8 | 71.1 | 74.3 | 74.3 | 74.3 | 54.9 | 77.6 | 74.3 | 84.0 | 74.3 | 87.3 | 64.6 | 84.0 | 80.8 | 93.7 |
|  |  | 3 | 71.1 | 71.1 | 64.6 | 74.3 | 67.9 | 67.9 | 74.3 | 74.3 | 64.6 | 74.3 | 74.3 | 71.1 | 77.6 | 87.3 | 67.9 | 90.5 | 74.3 | 100.2 |
| 8 | 7 | 1 | 64.6 | 64.6 | 64.6 | 64.6 | 77.6 | 71.1 | 74.3 | 80.8 | 58.2 | 74.3 | 74.3 | 64.6 | 67.9 | 54.9 | 51.7 | 71.1 | 67.9 | 67.9 |
|  |  | 2 | 64.6 | 74.3 | 67.9 | 74.3 | 74.3 | 74.3 | 74.3 | 90.5 | 74.3 | 74.3 | 77.6 | 67.9 | 67.9 | 67.9 | 58.2 | 71.1 | 74.3 | 74.3 |
|  |  | 3 | 61.4 | 71.1 | 71.1 | 69.9 | 64.6 | 74.3 | 71.1 | 74.3 | 71.1 | 80.8 | 80.8 | 67.9 | 61.4 | 64.6 | 61.4 | 64.6 | 74.3 | 67.9 |
|  | 9 | 1 | 74.3 | 80.8 | 74.3 | 77.6 | 74.3 | 77.6 | 71.1 | 74.3 | 90.5 | 64.6 | 93.7 | 74.3 | 77.6 | 84.0 | 80.8 | 67.9 | 87.3 | 80.8 |
|  |  | 2 | 87.3 | 87.3 | 77.6 | 74.3 | 74.3 | 77.6 | 71.1 | 74.3 | 87.3 | 80.8 | 87.3 | 74.3 | 74.3 | 84.0 | 80.8 | 74.3 | 84.0 | 84.0 |
|  |  | 3 | 84.0 | 77.6 | 74.3 | 77.6 | 80.8 | 74.3 | 71.1 | 74.3 | 74.3 | 74.3 | 87.3 | 74.3 | 87.3 | 80.8 | 87.3 | 67.9 | 90.5 | 80.8 |
|  | 11 | 1 | 90.5 | 84.0 | 77.6 | 80.8 | 80.8 | 77.6 | 74.3 | 74.3 | 90.5 | 77.6 | 77.6 | 87.3 | 87.3 | 93.7 | 74.3 | 64.6 | 90.5 | 84.0 |
|  |  | 2 | 87.3 | 84.0 | 77.6 | 77.6 | 77.6 | 74.3 | 74.3 | 90.5 | 74.3 | 74.3 | 93.7 | 96.9 | 90.5 | 90.5 | 87.3 | 74.3 | 84.0 | 77.6 |
|  |  | 3 | 84.0 | 74.3 | 71.1 | 77.6 | 90.5 | 71.1 | 77.6 | 77.6 | 77.6 | 77.6 | 84.0 | 84.9 | 93.7 | 90.5 | 77.6 | 84.0 | 84.0 | 80.8 |
|  | 13 | 1 | 74.3 | 87.3 | 71.1 | 74.3 | 64.6 | 84.0 | 87.3 | 64.5 | 80.8 | 74.3 | 80.8 | 93.7 | 93.7 | 87.3 | 80.8 | 84.0 | 71.1 | 61.4 |
|  |  | 2 | 77.6 | 77.6 | 64.6 | 67.9 | 80.8 | 80.8 | 87.3 | 74.3 | 87.3 | 74.3 | 74.3 | 80.8 | 84.0 | 80.8 | 84.0 | 87.3 | 80.8 | 71.1 |
|  |  | 3 | 87.3 | 80.8 | 61.4 | 64.6 | 80.8 | 80.8 | 90.5 | 77.6 | 74.3 | 77.6 | 74.3 | 77.6 | 84.0 | 74.3 | 77.6 | 84.0 | 74.3 | 71.1 |
| 9 | 7 | 1 | 71.1 | 74.3 | 84.0 | 61.4 | 77.6 | 74.3 | 84.0 | 74.3 | 58.2 | 64.6 | 64.6 | 87.3 | 61.4 | 74.3 | 58.2 | 71.1 | 71.1 | 74.3 |
|  |  | 2 | 64.6 | 61.4 | 58.2 | 64.6 | 64.6 | 64.6 | 84.0 | 80.8 | 58.2 | 74.3 | 67.9 | 77.6 | 67.9 | 74.3 | 58.2 | 64.6 | 74.3 | 90.5 |
|  |  | 3 | 71.1 | 64.6 | 21.7 | 67.3 | 71.1 | 74.3 | 71.1 | 84.0 | 58.2 | 64.6 | 64.6 | 74.3 | 54.9 | 74.3 | 54.9 | 74.3 | 64.6 | 96.9 |
|  | 9 | 1 | 90.5 | 80.8 | 106.6 | 93.7 | 100.2 | 87.3 | 74.3 | 74.3 | 74.3 | 80.8 | 77.6 | 71.1 | 58.2 | 84.0 | 74.3 | 64.6 | 84.0 | 74.3 |
|  |  | 2 | 90.5 | 84.0 | 96.9 | 87.3 | 103.4 | 96.9 | 77.6 | 84.0 | 64.6 | 74.3 | 51.7 | 74.3 | 74.3 | 74.3 | 74.3 | 74.3 | 80.8 | 74.3 |
|  |  | 3 | 90.5 | 84.0 | 103.4 | 96.2 | 106.6 | 93.7 | 87.3 | 80.8 | 64.6 | 84.0 | 54.9 | 61.9 | 74.3 | 74.3 | 67.9 | 80.8 | 67.9 | 77.6 |
|  | 11 | 1 | 54.9 | 64.6 | 58.2 | 71.1 | 84.0 | 87.3 | 64.6 | 80.8 | 84.0 | 80.8 | 100.2 | 90.5 | 54.9 | 74.3 | 61.4 | 71.1 | 77.6 | 84.0 |
|  |  | 2 | 48.5 | 67.9 | 48.5 | 77.6 | 80.8 | 74.3 | 77.6 | 74.3 | 80.8 | 77.6 | 90.5 | 96.9 | 51.7 | 74.3 | 61.4 | 74.3 | 74.3 | 74.3 |
|  |  | 3 | 54.9 | 59.2 | 54.9 | 67.2 | 40.3 | 74.3 | 93.7 | 93.7 | 96.9 | 77.6 | 87.3 | 93.7 | 58.2 | 71.1 | 74.3 | 74.3 | 74.3 | 71.1 |
|  | 13 | 1 | 61.4 | 80.8 | 58.2 | 64.6 | 93.7 | 93.7 | 103.4 | 103.4 | 61.4 | 64.6 | 74.3 | 87.3 | 90.5 | 93.7 | 51.7 | 58.2 | 93.7 | 90.5 |
|  |  | 2 | 58.2 | 54.9 | 58.2 | 64.6 | 87.3 | 93.7 | 100.2 | 103.4 | 74.3 | 74.3 | 58.2 | 80.8 | 80.8 | 96.9 | 48.5 | 51.7 | 100.2 | 100.2 |
|  |  | 3 | 51.7 | 67.9 | 61.4 | 64.6 | 93.7 | 93.7 | 90.5 | 93.7 | 67.9 | 58.2 | 61.4 | 77.6 | 84.0 | 90.5 | 61.4 | 61.4 | 93.7 | 106.6 |
| 10 | 7 | 1 | 35.5 | 25.9 | 30.8 | 38.8 | 51.7 | 48.5 | 67.9 | 77.6 | 45.2 | 54.9 | 61.4 | 67.9 | 32.3 | 51.7 | 67.9 | 84.0 | 58.2 | 58.2 |
|  |  | 2 | 29.1 | 38.8 | 45.2 | 48.5 | 51.7 | 51.7 | 58.2 | 84.0 | 51.7 | 61.4 | 58.2 | 74.3 | 42.0 | 38.8 | 64.6 | 71.1 | 61.4 | 67.9 |
|  |  | 3 | 35.5 | 38.8 | 45.2 | 61.4 | 61.4 | 58.2 | 64.6 | 74.3 | 48.5 | 61.4 | 67.9 | 71.1 | 51.7 | 38.8 | 54.9 | 74.3 | 51.7 | 67.9 |
|  | 9 | 1 | 38.8 | 45.2 | 54.9 | 64.6 | 61.4 | 64.6 | 58.2 | 54.2 | 48.5 | 64.6 | 74.3 | 74.3 | 54.9 | 54.9 | 38.8 | 35.5 | 74.3 | 74.3 |
|  |  | 2 | 51.7 | 51.7 | 64.6 | 58.2 | 64.6 | 58.2 | 64.6 | 54.9 | 64.6 | 54.9 | 67.9 | 74.3 | 51.7 | 61.4 | 58.2 | 51.7 | 64.6 | 64.6 |
|  |  | 3 | 42.0 | 48.5 | 61.4 | 54.9 | 67.9 | 61.4 | 51.7 | 64.6 | 64.6 | 54.9 | 67.9 | 71.1 | 61.4 | 54.9 | 42.0 | 54.9 | 58.2 | 74.3 |
|  | 11 | 1 | 51.7 | 38.8 | 45.2 | 12.9 | 54.9 | 42.0 | 54.9 | 58.2 | 38.8 | 48.5 | 48.5 | 48.5 | 35.5 | 38.8 | 84.0 | 71.1 | 67.9 | 64.6 |
|  |  | 2 | 54.9 | 42.0 | 51.7 | 16.2 | 51.7 | 61.4 | 71.1 | 45.2 | 38.8 | 45.2 | 54.9 | 45.2 | 38.8 | 42.0 | 74.3 | 74.3 | 64.6 | 67.9 |
|  |  | 3 | 54.9 | 48.5 | 51.7 | 12.9 | 54.9 | 49.9 | 54.9 | 45.2 | 51.7 | 58.2 | 42.0 | 45.2 | 38.8 | 51.7 | 71.1 | 74.3 | 58.2 | 71.1 |
|  | 13 | 1 | 71.1 | 74.3 | 64.6 | 58.2 | 42.0 | 51.7 | 58.2 | 54.9 | 45.2 | 58.2 | 54.9 | 45.7 | 64.6 | 64.6 | 71.1 | 74.3 | 64.6 | 74.3 |
|  |  | 2 | 64.6 | 67.9 | 61.4 | 61.4 | 35.5 | 48.2 | 61.4 | 54.9 | 51.7 | 58.2 | 45.2 | 51.7 | 51.7 | 74.3 | 74.3 | 84.0 | 74.3 | 84.0 |
|  |  | 3 | 64.6 | 71.1 | 74.3 | 61.4 | 38.8 | 45.2 | 54.9 | 45.2 | 48.5 | 51.7 | 48.5 | 48.5 | 51.7 | 74.3 | 71.1 | 77.6 | 74.3 | 84.0 |

APPENDIX F

VERTICAL PUSH AND PULL DATA

| SUB. | SIZE | R | SHAPE C PUSH | PULL | SHAPE D PUSH | PULL | SHAPE U PUSH | PULL | SHAPE T PUSH | PULL | SHAPE S PUSH | PULL | SHAPE W PUSH | PULL | SHAPE X PUSH | PULL | SHAPE Y PUSH | PULL | SHAPE Z PUSH | PULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 187.4 | 122.8 | 193.9 | 135.7 | 174.5 | 119.6 | 229.4 | 135.7 | 190.7 | 129.3 | 155.1 | 109.9 | 193.9 | 135.7 | 193.9 | 129.3 | 177.7 | 129.3 |
| | | 2 | 190.7 | 116.3 | 190.7 | 126.0 | 181.0 | 119.6 | 193.9 | 135.7 | 181.0 | 119.6 | 174.5 | 106.6 | 181.0 | 132.5 | 190.7 | 119.6 | 161.6 | 139.0 |
| | | 3 | 171.4 | 116.3 | 187.4 | 132.2 | 174.3 | 119.6 | 210.4 | 129.3 | 177.7 | 119.6 | 174.3 | 106.6 | 177.7 | 132.5 | 187.4 | 122.8 | 161.6 | 119.6 |
| | 9 | 1 | 193.9 | 126.0 | 184.2 | 132.5 | 197.1 | 119.0 | 226.2 | 129.3 | 187.4 | 119.6 | 190.7 | 129.3 | 203.6 | 129.3 | 151.9 | 77.6 | 213.3 | 120.0 |
| | | 2 | 177.7 | 122.8 | 171.3 | 119.6 | 197.1 | 122.8 | 216.5 | 122.8 | 193.9 | 122.8 | 181.0 | 126.0 | 181.0 | 126.0 | 151.9 | 64.6 | 181.0 | 126.0 |
| | | 3 | 184.2 | 122.8 | 190.7 | 122.8 | 193.9 | 122.8 | 197.1 | 126.0 | 197.1 | 129.3 | 164.8 | 119.6 | 155.1 | 122.8 | 150.3 | 96.9 | 174.5 | 122.8 |
| | 11 | 1 | 219.7 | 129.3 | 184.2 | 126.8 | 197.1 | 129.3 | 161.6 | 122.8 | 174.5 | 116.3 | 190.7 | 119.6 | 193.9 | 122.8 | 184.2 | 109.9 | 155.1 | 116.3 |
| | | 2 | 200.4 | 116.3 | 200.4 | 119.6 | 193.9 | 116.3 | 148.7 | 119.6 | 161.6 | 116.3 | 181.0 | 103.4 | 181.0 | 126.0 | 171.3 | 122.8 | 161.6 | 106.6 |
| | | 3 | 203.6 | 119.6 | 123.3 | 119.6 | 140.7 | 116.3 | 142.5 | 116.3 | 174.5 | 116.3 | 174.5 | 122.8 | 174.5 | 132.5 | 181.0 | 119.6 | 161.6 | 106.6 |
| | 13 | 1 | 193.9 | 122.8 | 164.8 | 103.4 | 200.4 | 129.3 | 171.3 | 126.0 | 223.0 | 119.6 | 158.3 | 106.6 | 187.4 | 119.6 | 187.4 | 106.6 | 148.7 | 109.9 |
| | | 2 | 200.4 | 106.6 | 155.1 | 103.4 | 190.7 | 129.3 | 148.7 | 119.6 | 203.6 | 119.6 | 155.1 | 96.9 | 181.0 | 116.3 | 164.8 | 106.6 | 155.1 | 116.3 |
| | | 3 | 190.7 | 113.1 | 173.5 | 120.9 | 184.2 | 129.0 | 132.5 | 119.6 | 203.6 | 80.8 | 155.1 | 100.8 | 174.5 | 119.8 | 151.9 | 119.3 | 223.0 | 106.6 |
| 2 | 7 | 1 | 239.1 | 87.3 | 235.9 | 96.9 | 223.0 | 77.6 | 223.0 | 77.6 | 223.0 | 80.8 | 245.6 | 100.2 | 229.4 | 87.3 | 232.7 | 103.4 | 248.8 | 93.7 |
| | | 2 | 219.7 | 84.0 | 213.3 | 109.9 | 239.1 | 77.6 | 216.5 | 87.3 | 219.7 | 93.7 | 245.6 | 113.1 | 229.4 | 90.5 | 235.9 | 106.6 | 239.1 | 96.9 |
| | | 3 | 232.2 | 93.7 | 229.2 | 113.1 | 229.3 | 77.6 | 216.2 | 77.3 | 216.2 | 74.3 | 239.1 | 106.6 | 213.7 | 74.3 | 216.5 | 113.1 | 223.0 | 100.2 |
| | 9 | 1 | 261.8 | 87.3 | 242.4 | 100.2 | 255.3 | 109.9 | 252.1 | 100.2 | 242.4 | 87.3 | 252.1 | 109.9 | 235.9 | 122.8 | 258.5 | 87.3 | 261.8 | 119.6 |
| | | 2 | 255.3 | 87.3 | 245.6 | 96.9 | 258.5 | 109.9 | 265.0 | 93.7 | 242.4 | 93.7 | 232.7 | 116.3 | 232.7 | 116.3 | 235.9 | 84.0 | 226.2 | 116.3 |
| | | 3 | 245.6 | 84.0 | 232.2 | 100.2 | 232.2 | 96.9 | 261.8 | 94.9 | 239.1 | 106.6 | 219.7 | 80.8 | 226.2 | 119.6 | 235.9 | 77.6 | 235.9 | 119.6 |
| | 11 | 1 | 239.1 | 77.6 | 239.1 | 113.1 | 274.7 | 103.4 | 245.6 | 93.7 | 248.8 | 103.4 | 248.8 | 103.4 | 200.4 | 77.6 | 239.1 | 106.6 | 258.5 | 103.4 |
| | | 2 | 239.1 | 80.8 | 245.6 | 116.3 | 206.8 | 74.3 | 235.7 | 113.1 | 216.5 | 106.6 | 239.1 | 103.4 | 206.8 | 93.7 | 239.1 | 109.9 | 242.4 | 103.4 |
| | | 3 | 223.0 | 87.3 | 235.3 | 109.9 | 200.4 | 67.3 | 242.4 | 103.4 | 213.3 | 87.3 | 235.9 | 106.6 | 203.6 | 84.0 | 232.7 | 113.1 | 245.6 | 106.6 |
| | 13 | 1 | 252.1 | 74.3 | 265.0 | 103.4 | 235.9 | 116.3 | 235.9 | 100.6 | 232.7 | 87.3 | 232.7 | 87.3 | 190.7 | 74.3 | 265.0 | 119.6 | 235.9 | 116.3 |
| | | 2 | 239.1 | 71.1 | 242.4 | 84.0 | 235.9 | 113.1 | 213.3 | 113.1 | 239.1 | 93.7 | 200.4 | 77.6 | 242.4 | 132.5 | 229.4 | 116.3 | 235.9 | 116.3 |
| | | 3 | 239.1 | 80.8 | 232.7 | 100.2 | 213.3 | 100.9 | 213.3 | 109.9 | 248.8 | 80.8 | 193.9 | 74.3 | 232.7 | 126.0 | 226.2 | 116.3 | 226.2 | 116.3 |
| 3 | 7 | 1 | 161.6 | 87.3 | 161.6 | 103.4 | 181.0 | 90.5 | 187.4 | 90.5 | 158.3 | 100.2 | 193.9 | 100.2 | 174.5 | 93.7 | 161.6 | 90.5 | 151.9 | 93.7 |
| | | 2 | 174.5 | 93.7 | 168.0 | 96.9 | 181.0 | 96.9 | 190.7 | 103.4 | 164.8 | 103.4 | 193.9 | 103.4 | 174.5 | 96.9 | 151.9 | 93.7 | 161.6 | 90.5 |
| | | 3 | 187.4 | 96.9 | 161.6 | 96.9 | 181.6 | 90.5 | 120.7 | 103.4 | 161.6 | 103.4 | 187.4 | 119.6 | 171.3 | 106.6 | 158.3 | 87.3 | 177.7 | 96.9 |
| | 9 | 1 | 174.5 | 84.0 | 161.6 | 96.9 | 190.7 | 93.7 | 174.5 | 100.2 | 171.3 | 77.6 | 190.7 | 100.2 | 193.9 | 100.2 | 161.6 | 67.9 | 151.9 | 96.9 |
| | | 2 | 184.2 | 93.7 | 129.3 | 93.7 | 164.8 | 96.9 | 181.0 | 100.2 | 184.2 | 84.0 | 181.0 | 100.2 | 193.9 | 113.1 | 164.8 | 77.6 | 155.1 | 93.7 |
| | | 3 | 190.7 | 100.2 | 142.2 | 100.2 | 187.4 | 87.3 | 184.2 | 103.4 | 177.7 | 84.0 | 181.0 | 109.9 | 184.2 | 109.9 | 155.1 | 74.3 | 148.7 | 90.5 |
| | 11 | 1 | 161.6 | 84.0 | 174.5 | 87.3 | 171.3 | 84.0 | 151.9 | 100.2 | 174.5 | 106.6 | 181.0 | 96.9 | 193.9 | 103.4 | 164.8 | 100.2 | 155.1 | 90.5 |
| | | 2 | 174.5 | 100.2 | 168.0 | 103.4 | 177.7 | 87.3 | 142.2 | 100.2 | 177.7 | 109.9 | 181.0 | 106.6 | 184.2 | 116.3 | 161.6 | 106.6 | 155.1 | 103.4 |
| | | 3 | 174.5 | 93.7 | 181.0 | 100.2 | 190.7 | 93.7 | 145.4 | 113.1 | 193.9 | 103.4 | 177.7 | 113.1 | 193.9 | 116.3 | 158.3 | 106.6 | 151.9 | 106.6 |
| | 13 | 1 | 161.6 | 87.3 | 164.8 | 96.9 | 158.3 | 71.1 | 151.9 | 100.2 | 155.1 | 93.7 | 168.0 | 90.5 | 177.7 | 106.6 | 171.3 | 84.0 | 184.2 | 93.7 |
| | | 2 | 164.8 | 84.0 | 151.9 | 100.2 | 151.9 | 77.6 | 142.2 | 103.4 | 151.9 | 90.5 | 181.0 | 106.6 | 161.6 | 100.2 | 168.0 | 103.4 | 177.7 | 116.3 |
| | | 3 | 161.6 | 90.5 | 158.3 | 100.2 | 132.5 | 80.8 | 145.4 | 103.4 | 158.3 | 100.2 | 187.4 | 106.6 | 164.8 | 96.9 | 142.2 | 113.1 | 193.9 | 106.6 |
| 4 | 7 | 1 | 177.7 | 96.9 | 158.3 | 93.7 | 171.3 | 90.5 | 158.3 | 90.5 | 151.9 | 109.9 | 206.8 | 96.9 | 145.4 | 100.2 | 181.0 | 87.3 | 197.7 | 87.3 |
| | | 2 | 90.5 | 93.7 | 135.7 | 90.5 | 164.8 | 90.5 | 148.7 | 87.3 | 151.9 | 109.9 | 161.6 | 100.2 | 132.5 | 96.9 | 161.6 | 90.5 | 184.2 | 84.0 |
| | | 3 | 151.9 | 100.2 | 139.0 | 87.3 | 174.5 | 80.8 | 135.7 | 84.0 | 126.0 | 116.3 | 161.6 | 90.5 | 142.2 | 93.7 | 158.3 | 84.0 | 184.2 | 84.0 |
| | 9 | 1 | 193.9 | 103.4 | 174.5 | 84.0 | 174.5 | 74.3 | 90.5 | 87.3 | 177.7 | 100.2 | 177.7 | 103.4 | 168.0 | 84.0 | 174.5 | 90.5 | 148.7 | 74.3 |
| | | 2 | 174.5 | 106.6 | 158.3 | 77.6 | 168.0 | 71.1 | 90.5 | 90.5 | 168.0 | 93.7 | 161.6 | 87.3 | 171.3 | 84.0 | 174.5 | 90.5 | 151.9 | 74.3 |
| | | 3 | 168.0 | 100.2 | 148.7 | 80.8 | 158.3 | 74.3 | 100.2 | 87.3 | 155.1 | 106.6 | 171.3 | 84.0 | 155.1 | 77.6 | 158.3 | 77.6 | 139.0 | 74.3 |
| | 11 | 1 | 193.9 | 96.9 | 177.7 | 87.3 | 171.3 | 66.9 | 181.0 | 77.6 | 161.6 | 90.8 | 193.9 | 87.3 | 177.7 | 84.0 | 151.9 | 84.0 | 177.7 | 96.9 |
| | | 2 | 177.7 | 96.9 | 164.8 | 80.8 | 158.3 | 96.9 | 168.0 | 77.6 | 142.2 | 80.8 | 190.7 | 87.3 | 161.6 | 84.0 | 151.9 | 77.6 | 184.2 | 100.2 |
| | | 3 | 164.8 | 90.5 | 161.6 | 87.3 | 164.8 | 80.8 | 164.8 | 84.0 | 155.1 | 74.3 | 203.6 | 80.8 | 148.7 | 87.3 | 145.4 | 67.9 | 155.1 | 90.5 |
| | 13 | 1 | 177.7 | 77.6 | 184.2 | 80.8 | 148.7 | 84.0 | 181.6 | 84.0 | 200.4 | 87.3 | 168.0 | 77.6 | 171.3 | 100.2 | 142.5 | 84.0 | 145.4 | 80.8 |
| | | 2 | 171.3 | 93.7 | 184.2 | 74.3 | 148.7 | 84.0 | 181.0 | 87.3 | 151.9 | 80.8 | 155.1 | 84.0 | 171.3 | 100.2 | 132.5 | 87.3 | 145.7 | 77.6 |
| | | 3 | 145.5 | 84.0 | 184.2 | 71.1 | 151.9 | 87.3 | 158.3 | 84.0 | 142.2 | 74.3 | 142.2 | 80.8 | 168.0 | 100.5 | 132.5 | 80.8 | 146.7 | 74.3 |
| 5 | 7 | 1 | 155.1 | 100.2 | 155.1 | 84.0 | 171.3 | 103.4 | 164.8 | 84.0 | 168.0 | 100.2 | 158.3 | 96.9 | 181.0 | 106.6 | 164.8 | 109.9 | 151.9 | 106.6 |
| | | 2 | 151.9 | 109.9 | 155.1 | 100.2 | 168.0 | 96.9 | 155.1 | 84.0 | 158.3 | 87.3 | 161.6 | 106.6 | 177.7 | 109.9 | 174.5 | 96.9 | 158.3 | 103.4 |
| | | 3 | 164.8 | 106.6 | 161.6 | 90.5 | 168.0 | 106.6 | 161.6 | 87.3 | 161.6 | 103.4 | 158.3 | 100.2 | 174.5 | 106.6 | 151.9 | 84.0 | 161.6 | 109.9 |
| | 9 | 1 | 174.5 | 87.3 | 148.7 | 90.5 | 174.5 | 96.9 | 174.5 | 106.6 | 155.1 | 106.6 | 171.3 | 103.4 | 168.0 | 100.2 | 164.8 | 96.9 | 158.3 | 90.5 |
| | | 2 | 174.5 | 87.3 | 151.9 | 87.3 | 164.8 | 109.9 | 155.1 | 106.6 | 164.8 | 77.6 | 184.2 | 103.4 | 174.5 | 100.2 | 148.7 | 100.2 | 155.1 | 80.8 |
| | | 3 | 155.1 | 90.5 | 158.3 | 93.7 | 151.9 | 106.6 | 151.9 | 103.4 | 171.3 | 87.3 | 171.3 | 103.4 | 168.0 | 100.2 | 151.9 | 100.2 | 155.1 | 80.8 |
| | 11 | 1 | 151.9 | 74.3 | 155.1 | 96.9 | 145.4 | 96.9 | 129.3 | 119.6 | 139.0 | 80.8 | 174.5 | 96.9 | 164.8 | 100.2 | 155.1 | 106.6 | 174.5 | 103.4 |
| | | 2 | 148.7 | 84.0 | 145.4 | 90.5 | 148.7 | 106.6 | 116.3 | 116.3 | 148.7 | 90.5 | 151.9 | 84.0 | 171.3 | 93.7 | 151.9 | 100.2 | 151.9 | 96.9 |
| | | 3 | 151.9 | 84.0 | 145.4 | 93.7 | 142.2 | 100.2 | 135.7 | 96.9 | 155.1 | 90.5 | 148.7 | 90.5 | 193.9 | 100.2 | 155.1 | 103.4 | 148.7 | 103.4 |
| | 13 | 1 | 166.0 | 80.8 | 151.9 | 103.4 | 122.8 | 109.9 | 109.9 | 145.4 | 145.4 | 96.9 | 164.8 | 100.2 | 132.5 | 96.9 | 161.6 | 100.2 | 164.8 | 106.6 |
| | | 2 | 171.3 | 87.3 | 151.9 | 100.2 | 129.3 | 103.4 | 113.1 | 135.7 | 142.2 | 93.7 | 151.9 | 100.2 | 132.5 | 96.9 | 155.1 | 109.9 | 151.9 | 103.4 |

(TO BE CONTINUED)

| SUB. SIZE | | R | SHAPE C | | SHAPE D | | SHAPE Q | | SHAPE T | | SHAPE S | | SHAPE W | | SHAPE X | | SHAPE Y | | SHAPE Z | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL | PUSH | PULL |
| 6 | 7 | 1 | 151.9 | 106.6 | 177.7 | 109.9 | 148.7 | 96.9 | 129.3 | 106.6 | 135.7 | 90.5 | 142.2 | 96.9 | 148.7 | 113.1 | 119.6 | 87.3 | 109.9 | 74.3 |
| | | 2 | 145.4 | 109.9 | 177.7 | 116.3 | 129.3 | 106.6 | 126.0 | 100.2 | 122.8 | 87.3 | 148.7 | 90.5 | 145.4 | 100.2 | 109.9 | 77.6 | 100.2 | 74.3 |
| | | 3 | 132.5 | 116.3 | 164.8 | 109.9 | 122.8 | 103.4 | 126.0 | 103.4 | 100.2 | 84.0 | 151.9 | 77.6 | 139.0 | 109.9 | 126.0 | 87.3 | 103.4 | 74.3 |
| | 9 | 1 | 116.3 | 80.8 | 116.3 | 90.5 | 151.9 | 96.9 | 142.2 | 106.6 | 155.1 | 106.6 | 135.7 | 96.9 | 135.7 | 96.9 | 161.6 | 100.2 | 145.4 | 103.4 |
| | | 2 | 148.7 | 90.5 | 113.1 | 90.5 | 135.7 | 96.9 | 139.0 | 106.6 | 142.2 | 103.4 | 142.2 | 87.3 | 132.5 | 93.7 | 155.1 | 90.5 | 139.0 | 113.1 |
| | | 3 | 122.8 | 84.0 | 119.6 | 93.7 | 142.2 | 93.7 | 132.5 | 100.2 | 145.4 | 106.6 | 119.6 | 90.5 | 139.0 | 94.9 | 139.0 | 87.3 | 139.0 | 100.2 |
| | 11 | 1 | 158.3 | 87.3 | 126.0 | 93.7 | 135.7 | 90.5 | 74.5 | 87.3 | 151.9 | 64.6 | 148.7 | 96.9 | 119.6 | 100.2 | 151.9 | 84.0 | 148.7 | 87.3 |
| | | 2 | 151.9 | 106.6 | 116.3 | 90.5 | 151.9 | 106.6 | 77.7 | 90.5 | 145.4 | 96.9 | 142.2 | 106.6 | 126.0 | 106.6 | 129.3 | 74.3 | 135.7 | 93.7 |
| | | 3 | 139.0 | 93.7 | 119.0 | 100.2 | 151.9 | 90.5 | 68.0 | 100.2 | 133.7 | 100.2 | 148.7 | 103.4 | 151.9 | 103.4 | 129.3 | 77.6 | 142.2 | 90.5 |
| | 13 | 1 | 145.4 | 80.8 | 135.7 | 87.3 | 142.2 | 87.3 | 116.3 | 90.5 | 129.3 | 74.3 | 142.2 | 103.4 | 129.3 | 100.2 | 126.0 | 93.7 | 116.3 | 87.3 |
| | | 2 | 132.5 | 80.8 | 132.5 | 77.6 | 142.2 | 103.4 | 113.1 | 90.5 | 126.0 | 74.3 | 126.0 | 96.9 | 129.3 | 96.9 | 116.3 | 90.5 | 103.4 | 80.8 |
| | | 3 | 135.7 | 87.3 | 139.0 | 67.9 | 145.4 | 90.5 | 109.9 | 93.7 | 100.2 | 71.1 | 113.1 | 87.3 | 122.8 | 96.9 | 126.0 | 93.7 | 100.2 | 90.5 |
| 7 | 7 | 1 | 164.8 | 106.6 | 158.3 | 109.9 | 168.0 | 96.9 | 151.9 | 84.0 | 164.8 | 109.9 | 164.8 | 109.9 | 158.3 | 113.1 | 74.5 | 109.9 | 148.7 | 96.9 |
| | | 2 | 155.1 | 84.0 | 151.9 | 113.1 | 164.8 | 100.2 | 145.4 | 90.5 | 164.8 | 116.3 | 177.7 | 113.1 | 171.3 | 122.8 | 155.1 | 113.1 | 151.9 | 90.5 |
| | | 3 | 155.1 | 106.6 | 158.3 | 116.3 | 164.8 | 106.6 | 135.7 | 84.0 | 155.1 | 109.9 | 161.6 | 116.3 | 158.3 | 126.0 | 155.1 | 109.9 | 148.7 | 90.5 |
| | 9 | 1 | 177.7 | 116.3 | 181.0 | 103.4 | 164.8 | 106.6 | 184.2 | 122.8 | 155.1 | 96.9 | 161.6 | 116.3 | 151.9 | 109.9 | 164.8 | 119.6 | 177.7 | 106.6 |
| | | 2 | 171.3 | 113.1 | 161.6 | 103.4 | 164.8 | 100.2 | 174.5 | 122.8 | 168.0 | 96.9 | 164.8 | 119.6 | 151.9 | 116.3 | 161.6 | 119.6 | 177.7 | 96.9 |
| | | 3 | 181.0 | 119.6 | 158.3 | 113.1 | 158.3 | 103.4 | 174.5 | 116.3 | 174.5 | 100.2 | 171.3 | 103.4 | 155.1 | 113.1 | 148.8 | 119.6 | 164.8 | 106.6 |
| | 11 | 1 | 164.8 | 96.9 | 158.3 | 113.1 | 171.3 | 103.4 | 161.6 | 119.6 | 74.3 | 116.3 | 168.0 | 100.2 | 168.0 | 122.8 | 164.8 | 119.6 | 161.6 | 116.3 |
| | | 2 | 168.0 | 106.6 | 151.9 | 122.8 | 161.6 | 100.2 | 151.9 | 119.6 | 154.8 | 113.1 | 161.6 | 106.6 | 177.7 | 119.6 | 168.0 | 119.6 | 155.1 | 119.6 |
| | | 3 | 155.1 | 100.2 | 151.9 | 106.6 | 168.0 | 106.6 | 145.4 | 106.6 | 161.6 | 113.1 | 158.3 | 100.2 | 161.6 | 116.3 | 161.6 | 119.6 | 145.4 | 103.4 |
| | 13 | 1 | 190.7 | 77.6 | 161.6 | 56.9 | 177.7 | 56.9 | 174.5 | 119.6 | 161.6 | 103.4 | 148.7 | 93.7 | 171.3 | 113.1 | 161.6 | 113.1 | 164.8 | 116.3 |
| | | 2 | 187.4 | 80.8 | 155.1 | 77.6 | 174.5 | 56.9 | 184.2 | 109.9 | 161.6 | 90.5 | 155.1 | 90.5 | 168.0 | 113.1 | 148.7 | 113.1 | 155.1 | 116.3 |
| | | 3 | 184.2 | 80.8 | 148.0 | 80.8 | 184.2 | 90.5 | 177.7 | 113.1 | 161.6 | 106.6 | 151.9 | 96.9 | 161.6 | 109.9 | 151.9 | 109.9 | 151.9 | 113.1 |
| 8 | 7 | 1 | 119.6 | 67.9 | 126.0 | 50.5 | 126.0 | 80.8 | 119.6 | 80.8 | 129.3 | 84.0 | 126.0 | 77.6 | 113.1 | 74.3 | 132.5 | 84.0 | 129.3 | 80.8 |
| | | 2 | 126.0 | 74.3 | 122.8 | 90.5 | 135.7 | 77.6 | 123.3 | 74.3 | 119.6 | 84.0 | 132.5 | 87.3 | 109.9 | 71.1 | 119.6 | 71.1 | 122.8 | 74.3 |
| | | 3 | 126.0 | 67.9 | 129.3 | 94.0 | 122.4 | 74.3 | 120.0 | 74.3 | 116.3 | 84.0 | 129.3 | 80.8 | 135.7 | 71.1 | 129.3 | 67.9 | 126.0 | 74.3 |
| | 9 | 1 | 125.3 | 64.6 | 132.5 | 74.3 | 132.5 | 74.3 | 116.3 | 74.3 | 129.3 | 80.8 | 113.1 | 77.6 | 135.7 | 71.1 | 119.6 | 71.1 | 135.7 | 74.3 |
| | | 2 | 116.3 | 67.9 | 119.6 | 64.6 | 132.5 | 74.3 | 103.4 | 74.3 | 103.4 | 74.3 | 109.9 | 84.0 | 132.5 | 77.6 | 122.8 | 74.3 | 135.7 | 74.3 |
| | | 3 | 129.3 | 74.3 | 116.3 | 67.9 | 129.3 | 80.8 | 116.3 | 67.9 | 126.0 | 77.6 | 116.3 | 74.3 | 122.8 | 77.6 | 126.0 | 74.3 | 139.0 | 77.6 |
| | 11 | 1 | 122.8 | 71.1 | 139.0 | 74.3 | 139.0 | 74.3 | 103.4 | 74.3 | 129.3 | 80.8 | 148.7 | 77.6 | 139.0 | 90.5 | 148.7 | 80.8 | 139.0 | 87.3 |
| | | 2 | 119.6 | 74.3 | 139.0 | 74.3 | 139.0 | 74.3 | 116.3 | 74.3 | 119.6 | 74.3 | 135.7 | 71.1 | 116.3 | 77.6 | 132.5 | 84.0 | 132.5 | 87.3 |
| | | 3 | 119.6 | 74.3 | 122.8 | 49.0 | 119.0 | 74.3 | 122.8 | 71.1 | 139.0 | 77.6 | 126.0 | 74.3 | 129.3 | 74.3 | 142.2 | 87.3 | 151.9 | 80.8 |
| | 13 | 1 | 132.5 | 67.9 | 132.5 | 74.3 | 142.2 | 80.8 | 132.5 | 71.1 | 132.5 | 71.1 | 116.3 | 74.3 | 129.3 | 84.0 | 129.3 | 77.6 | 132.5 | 77.6 |
| | | 2 | 142.2 | 67.9 | 119.6 | 74.3 | 126.0 | 77.6 | 122.8 | 74.3 | 129.3 | 74.3 | 122.8 | 71.1 | 109.9 | 77.6 | 109.9 | 87.3 | 132.5 | 74.3 |
| | | 3 | 113.1 | 64.6 | 129.3 | 71.1 | 119.6 | 74.3 | 129.3 | 74.3 | 129.3 | 74.3 | 119.6 | 74.3 | 126.0 | 84.0 | 142.2 | 74.3 | 119.6 | 48.5 |
| 9 | 7 | 1 | 184.2 | 119.6 | 161.6 | 100.6 | 174.5 | 113.1 | 151.9 | 96.9 | 197.1 | 119.6 | 155.1 | 84.0 | 190.7 | 119.6 | 158.3 | 100.2 | 155.1 | 74.3 |
| | | 2 | 164.8 | 113.1 | 161.6 | 113.1 | 187.4 | 113.1 | 151.9 | 77.6 | 193.9 | 122.8 | 148.7 | 93.7 | 190.7 | 119.6 | 151.9 | 113.1 | 148.7 | 74.3 |
| | | 3 | 168.0 | 116.3 | 155.1 | 116.3 | 181.0 | 113.1 | 151.9 | 77.6 | 200.4 | 116.3 | 151.9 | 84.0 | 200.4 | 119.6 | 164.8 | 87.3 | 155.1 | 74.3 |
| | 9 | 1 | 171.3 | 109.9 | 135.7 | 93.7 | 168.0 | 93.7 | 177.7 | 106.6 | 177.7 | 116.3 | 197.1 | 113.1 | 177.7 | 113.1 | 164.8 | 100.2 | 74.5 | 74.3 |
| | | 2 | 190.7 | 100.2 | 132.5 | 96.9 | 164.8 | 96.9 | 181.0 | 109.9 | 181.0 | 109.9 | 181.0 | 113.1 | 177.7 | 119.6 | 142.2 | 103.4 | 155.1 | 74.3 |
| | | 3 | 193.9 | 100.2 | 164.8 | 87.3 | 181.0 | 100.2 | 174.5 | 109.9 | 161.6 | 116.3 | 190.7 | 113.1 | 174.5 | 119.6 | 151.9 | 109.9 | 155.1 | 74.3 |
| | 11 | 1 | 164.8 | 84.0 | 142.2 | 74.3 | 155.1 | 80.8 | 181.0 | 116.3 | 174.5 | 90.5 | 190.7 | 100.2 | 190.7 | 119.6 | 151.9 | 103.4 | 161.6 | 103.4 |
| | | 2 | 184.2 | 84.0 | 151.9 | 71.1 | 135.7 | 84.0 | 187.4 | 109.9 | 161.6 | 90.5 | 181.0 | 103.4 | 190.7 | 116.3 | 142.2 | 100.2 | 164.8 | 87.3 |
| | | 3 | 168.0 | 84.0 | 148.7 | 74.3 | 139.0 | 87.3 | 177.7 | 116.3 | 155.1 | 80.8 | 181.0 | 103.4 | 181.0 | 113.1 | 142.2 | 90.5 | 123.3 | 100.2 |
| | 13 | 1 | 193.9 | 96.9 | 168.0 | 87.3 | 151.9 | 87.3 | 119.6 | 80.8 | 177.7 | 103.4 | 161.6 | 103.4 | 168.0 | 100.2 | 174.5 | 116.3 | 155.1 | 77.6 |
| | | 2 | 181.0 | 93.7 | 168.0 | 84.0 | 148.7 | 84.0 | 148.7 | 80.8 | 161.6 | 93.7 | 171.3 | 100.2 | 145.4 | 93.7 | 161.6 | 113.1 | 122.8 | 80.8 |
| | | 3 | 181.0 | 93.7 | 155.1 | 84.0 | 155.1 | 80.8 | 142.2 | 87.3 | 171.3 | 103.4 | 168.0 | 93.7 | 155.1 | 100.2 | 174.5 | 116.3 | 129.3 | 74.3 |
| 10 | 7 | 1 | 184.2 | 132.5 | 174.5 | 132.5 | 190.7 | 132.5 | 190.7 | 139.0 | 171.3 | 142.2 | 184.2 | 151.9 | 197.1 | 168.0 | 200.4 | 126.0 | 158.3 | 151.9 |
| | | 2 | 164.8 | 139.0 | 145.4 | 142.2 | 177.7 | 132.5 | 193.9 | 145.4 | 168.0 | 135.7 | 200.4 | 151.9 | 190.7 | 181.0 | 187.4 | 135.7 | 155.1 | 151.9 |
| | | 3 | 164.8 | 142.2 | 161.6 | 139.0 | 177.7 | 129.3 | 145.4 | 171.1 | 161.6 | 151.9 | 200.4 | 158.3 | 190.7 | 164.8 | 174.5 | 116.3 | 148.7 | 151.9 |
| | 9 | 1 | 193.9 | 135.0 | 184.2 | 148.7 | 187.4 | 164.8 | 174.5 | 155.1 | 174.5 | 151.9 | 164.8 | 155.1 | 174.5 | 139.0 | 168.0 | 154.3 | 171.3 | 161.6 |
| | | 2 | 190.7 | 145.4 | 171.3 | 161.6 | 181.0 | 161.6 | 174.5 | 142.2 | 151.9 | 148.7 | 177.7 | 139.0 | 164.8 | 155.1 | 177.7 | 151.9 | 174.5 | 164.8 |
| | | 3 | 184.2 | 142.2 | 193.9 | 171.3 | 181.0 | 174.5 | 155.1 | 142.2 | 161.6 | 155.1 | 171.3 | 135.7 | 184.2 | 142.2 | 190.7 | 151.9 | 168.0 | 161.6 |
| | 11 | 1 | 193.9 | 151.9 | 193.9 | 145.4 | 200.4 | 158.3 | 174.5 | 158.3 | 193.9 | 155.1 | 184.2 | 168.0 | 164.8 | 139.0 | 168.0 | 155.1 | 158.3 | 155.1 |
| | | 2 | 193.9 | 151.9 | 187.4 | 148.7 | 206.8 | 161.6 | 135.7 | 135.7 | 190.7 | 145.4 | 187.4 | 158.3 | 164.8 | 174.5 | 177.7 | 168.0 | 187.4 | 155.1 |
| | | 3 | 193.9 | 158.3 | 193.9 | 145.4 | 203.6 | 161.6 | 145.4 | 142.2 | 164.8 | 132.5 | 181.0 | 164.8 | 181.0 | 164.8 | 184.2 | 151.9 | 184.2 | 171.3 |
| | 13 | 1 | 187.4 | 139.0 | 197.1 | 155.1 | 181.0 | 135.7 | 139.0 | 158.3 | 187.4 | 135.7 | 155.1 | 151.9 | 187.4 | 139.0 | 187.4 | 171.3 | 158.3 | 135.7 |
| | | 2 | 151.9 | 145.4 | 164.8 | 171.3 | 184.2 | 145.4 | 135.7 | 158.3 | 184.2 | 135.7 | 151.9 | 148.7 | 187.4 | 151.9 | 168.0 | 174.5 | 177.7 | 145.4 |
| | | 3 | 155.1 | 139.0 | 190.7 | 155.1 | 184.2 | 155.1 | 122.8 | 151.9 | 171.3 | 132.5 | 151.9 | 164.8 | 158.0 | 151.9 | 193.9 | 148.7 | 177.7 | 145.4 |

GENDER : FEMALE   VERTICAL

| SUB. SIZE | R | SHAPE C PUSH PULL | SHAPE D PUSH PULL | SHAPE T PUSH PULL | SHAPE S PUSH PULL | SHAPE W PUSH PULL | SHAPE X PUSH PULL | SHAPE Y PUSH PULL | SHAPE Z PUSH PULL |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | | | | | | | | |
|   | 9 | | | | | | | | |
|   | 11 | | | | | | | | |
|   | 13 | | | | | | | | |
| 2 | 7 | | | | | | | | |
|   | 9 | | | | | | | | |
|   | 11 | | | | | | | | |
|   | 13 | | | | | | | | |
| 3 | 7 | | | | | | | | |
|   | 9 | | | | | | | | |
|   | 11 | | | | | | | | |
|   | 13 | | | | | | | | |
| 4 | 7 | | | | | | | | |
|   | 9 | | | | | | | | |
|   | 11 | | | | | | | | |
|   | 13 | | | | | | | | |
| 5 | 7 | | | | | | | | |
|   | 9 | | | | | | | | |
|   | 11 | | | | | | | | |
|   | 13 | | | | | | | | |

(TO BE CONTINUED)

| SUB. | SIZE | R | SHAPE C PUSH | PULL | SHAPE D PUSH | PULL | SHAPE Q PUSH | PULL | SHAPE T PUSH | PULL | SHAPE S PUSH | PULL | SHAPE W PUSH | PULL | SHAPE X PUSH | PULL | SHAPE Y PUSH | PULL | SHAPE Z PUSH | PULL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 1 | 96.9 | 71.1 | 109.9 | 84.0 | 84.0 | 74.3 | 106.6 | 80.8 | 100.2 | 87.3 | 96.9 | 80.8 | 103.4 | 84.0 | 90.5 | 80.8 | 100.2 | 77.6 |
| | | 2 | 96.9 | 74.3 | 109.9 | 77.6 | 87.3 | 74.3 | 103.4 | 87.3 | 93.7 | 77.6 | 84.0 | 77.6 | 96.9 | 74.3 | 90.5 | 77.6 | 80.8 | 80.8 |
| | | 3 | 106.6 | 74.3 | 111.1 | 74.3 | 84.0 | 74.3 | 84.3 | 39.8 | 100.2 | 80.8 | 77.6 | 80.8 | 87.3 | 80.8 | 87.3 | 80.8 | 84.0 | 80.8 |
| | 9 | 1 | 132.5 | 80.8 | 103.4 | 74.3 | 100.2 | 64.6 | 113.1 | 93.7 | 100.2 | 74.3 | 106.6 | 80.8 | 106.6 | 71.1 | 87.3 | 67.9 | 96.9 | 51.7 |
| | | 2 | 132.5 | 80.8 | 100.2 | 71.1 | 109.9 | 67.9 | 100.2 | 87.3 | 87.3 | 74.3 | 103.4 | 80.8 | 109.9 | 71.1 | 77.6 | 74.3 | 96.9 | 48.5 |
| | | 3 | 113.1 | 74.3 | 100.2 | 64.6 | 109.9 | 74.3 | 90.5 | 80.8 | 93.7 | 74.3 | 84.0 | 74.3 | 100.2 | 61.4 | 87.3 | 71.1 | 93.7 | 45.2 |
| | 11 | 1 | 113.1 | 71.1 | 116.3 | 74.3 | 129.3 | 77.6 | 96.9 | 74.3 | 90.5 | 58.2 | 126.0 | 71.1 | 77.6 | 51.7 | 116.3 | 74.3 | 106.6 | 80.8 |
| | | 2 | 116.3 | 74.3 | 106.6 | 71.1 | 116.3 | 80.8 | 80.8 | 71.1 | 93.7 | 54.9 | 103.4 | 67.9 | 77.6 | 54.9 | 106.6 | 64.6 | 100.2 | 71.1 |
| | | 3 | 93.7 | 67.9 | 106.6 | 64.6 | 100.2 | 74.3 | 77.6 | 74.3 | 80.8 | 64.6 | 113.1 | 67.9 | 90.5 | 71.1 | 100.2 | 72.1 | 96.9 | 71.1 |
| | 13 | 1 | 109.9 | 77.6 | 113.1 | 74.3 | 116.3 | 74.3 | 74.3 | 77.6 | 106.6 | 71.1 | 96.9 | 80.8 | 67.9 | 80.8 | 109.9 | 64.6 | 93.7 | 64.6 |
| | | 2 | 106.6 | 74.3 | 100.2 | 64.6 | 109.9 | 74.3 | 74.3 | 77.6 | 96.9 | 74.3 | 109.9 | 71.1 | 74.3 | 74.3 | 90.5 | 67.9 | 80.8 | 61.4 |
| | | 3 | 103.4 | 71.1 | 90.5 | 64.6 | 103.4 | 74.3 | 74.3 | 77.6 | 87.3 | 74.3 | 100.2 | 64.6 | 80.8 | 44.3 | 77.6 | 71.1 | 77.6 | 67.9 |
| 7 | 7 | 1 | 103.4 | 90.5 | 113.1 | 50.5 | 109.9 | 93.7 | 109.9 | 83.3 | 116.3 | 100.2 | 116.3 | 80.8 | 100.2 | 97.6 | 90.5 | 71.1 | 84.0 | 67.9 |
| | | 2 | 84.0 | 96.9 | 80.8 | 90.5 | 96.9 | 90.5 | 96.9 | 77.6 | 106.6 | 90.5 | 90.5 | 80.8 | 90.5 | 74.3 | 84.0 | 77.6 | 84.0 | 80.8 |
| | | 3 | 84.0 | 93.7 | 93.7 | 93.7 | 84.0 | 84.0 | 102.9 | 74.3 | 100.2 | 74.3 | 100.2 | 74.3 | 90.5 | 74.3 | 71.1 | 74.3 | 71.1 | 71.1 |
| | 9 | 1 | 119.6 | 80.8 | 100.2 | 74.3 | 116.3 | 84.0 | 113.1 | 96.9 | 96.9 | 87.3 | 109.9 | 87.3 | 96.9 | 80.8 | 100.2 | 74.3 | 96.9 | 93.7 |
| | | 2 | 106.6 | 74.3 | 74.3 | 96.9 | 106.6 | 84.0 | 93.7 | 100.2 | 93.7 | 93.7 | 106.6 | 84.0 | 74.3 | 74.3 | 103.4 | 77.6 | 90.5 | 90.5 |
| | | 3 | 113.1 | 74.3 | 106.6 | 77.6 | 96.9 | 80.8 | 96.9 | 94.9 | 90.5 | 90.5 | 87.3 | 87.3 | 84.0 | 74.3 | 93.7 | 77.6 | 84.0 | 84.0 |
| | 11 | 1 | 139.0 | 74.3 | 93.7 | 74.3 | 116.3 | 77.6 | 100.2 | 90.5 | 116.3 | 84.0 | 106.6 | 74.3 | 113.1 | 80.8 | 96.9 | 74.3 | 90.5 | 74.3 |
| | | 2 | 116.3 | 74.3 | 103.4 | 74.3 | 103.4 | 84.0 | 87.3 | 87.3 | 113.1 | 77.6 | 96.9 | 87.3 | 100.2 | 77.6 | 77.6 | 74.3 | 77.6 | 74.3 |
| | | 3 | 116.3 | 77.6 | 93.7 | 74.3 | 106.6 | 74.3 | 100.2 | 77.6 | 104.9 | 84.0 | 93.7 | 80.8 | 103.4 | 77.6 | 77.6 | 61.4 | 71.1 | 74.3 |
| | 13 | 1 | 109.9 | 67.9 | 106.6 | 71.1 | 106.6 | 71.1 | 87.3 | 74.3 | 103.4 | 84.0 | 96.9 | 74.3 | 116.3 | 80.8 | 96.9 | 87.3 | 106.6 | 90.5 |
| | | 2 | 109.9 | 64.6 | 109.9 | 74.3 | 109.9 | 77.6 | 71.1 | 74.3 | 103.4 | 84.0 | 103.4 | 74.3 | 115.6 | 74.3 | 96.9 | 77.6 | 96.9 | 71.1 |
| | | 3 | 100.2 | 67.9 | 100.2 | 64.6 | 113.7 | 74.3 | 109.9 | 74.3 | 109.9 | 74.3 | 90.5 | 74.3 | 100.2 | 74.3 | 77.6 | 74.3 | 112.1 | 84.0 |
| 8 | 7 | 1 | 90.5 | 84.0 | 100.2 | 64.6 | 116.3 | 84.0 | 126.0 | 90.5 | 116.3 | 96.9 | 116.3 | 84.0 | 96.9 | 74.3 | 116.3 | 84.0 | 106.6 | 74.3 |
| | | 2 | 116.3 | 80.8 | 106.6 | 74.3 | 116.3 | 87.3 | 116.3 | 93.7 | 109.9 | 87.3 | 106.6 | 84.0 | 96.9 | 84.0 | 103.4 | 87.3 | 103.4 | 74.3 |
| | | 3 | 119.3 | 77.6 | 96.9 | 77.6 | 113.1 | 84.0 | 96.9 | 90.5 | 103.4 | 84.0 | 113.1 | 90.5 | 96.9 | 80.8 | 93.7 | 80.8 | 93.7 | 80.8 |
| | 9 | 1 | 135.7 | 87.3 | 77.6 | 64.6 | 93.7 | 71.1 | 84.0 | 122.8 | 126.0 | 93.7 | 119.6 | 87.3 | 106.6 | 87.3 | 116.3 | 74.3 | 106.6 | 74.3 |
| | | 2 | 126.0 | 84.0 | 100.2 | 74.3 | 109.9 | 71.1 | 80.8 | 109.9 | 116.3 | 93.7 | 122.8 | 80.8 | 116.3 | 96.9 | 96.9 | 77.6 | 103.4 | 80.8 |
| | | 3 | 126.0 | 84.0 | 100.2 | 74.3 | 113.1 | 74.3 | 80.8 | 109.9 | 113.1 | 87.3 | 100.2 | 84.0 | 106.6 | 80.8 | 96.9 | 71.1 | 109.9 | 80.8 |
| | 11 | 1 | 113.1 | 74.3 | 116.3 | 90.5 | 116.3 | 84.0 | 96.9 | 74.3 | 119.6 | 80.8 | 106.6 | 61.4 | 106.6 | 80.8 | 103.4 | 74.3 | 109.9 | 80.8 |
| | | 2 | 129.3 | 74.3 | 106.6 | 93.7 | 113.1 | 84.0 | 80.8 | 74.3 | 113.1 | 74.3 | 96.9 | 67.9 | 109.9 | 74.3 | 103.4 | 71.1 | 106.6 | 84.0 |
| | | 3 | 106.6 | 71.1 | 113.1 | 53.7 | 109.9 | 74.3 | 84.0 | 80.8 | 103.4 | 74.3 | 106.6 | 71.1 | 103.4 | 77.6 | 103.4 | 74.3 | 113.1 | 74.3 |
| | 13 | 1 | 103.4 | 77.6 | 93.7 | 67.9 | 109.9 | 74.3 | 109.9 | 77.6 | 109.9 | 74.3 | 103.4 | 77.6 | 96.9 | 74.3 | 103.4 | 74.3 | 90.5 | 64.6 |
| | | 2 | 113.1 | 71.1 | 96.9 | 64.6 | 116.3 | 74.3 | 126.0 | 74.3 | 113.1 | 90.5 | 100.2 | 74.3 | 87.3 | 71.1 | 90.5 | 77.6 | 106.6 | 64.6 |
| | | 3 | 106.6 | 71.1 | 96.9 | 74.3 | 113.1 | 67.9 | 106.6 | 74.3 | 93.7 | 77.6 | 109.9 | 74.3 | 93.7 | 74.3 | 103.4 | 80.8 | 106.6 | 67.9 |
| 9 | 7 | 1 | 135.0 | 77.6 | 126.0 | 74.3 | 129.3 | 84.0 | 139.0 | 80.8 | 126.0 | 74.3 | 113.1 | 77.6 | 103.4 | 90.5 | 93.7 | 74.3 | 126.0 | 80.8 |
| | | 2 | 142.2 | 84.0 | 119.6 | 74.3 | 119.6 | 90.5 | 145.4 | 84.0 | 119.6 | 74.3 | 119.6 | 90.5 | 116.3 | 100.2 | 71.1 | 74.3 | 122.8 | 87.3 |
| | | 3 | 142.2 | 90.5 | 122.8 | 77.6 | 113.1 | 84.0 | 122.8 | 77.6 | 96.9 | 90.5 | 116.3 | 90.5 | 77.6 | 74.3 | 122.8 | | 116.3 | |
| | 9 | 1 | 148.7 | 77.6 | 126.0 | 90.5 | 145.4 | 87.3 | 116.3 | 80.8 | 129.3 | 80.8 | 119.6 | 74.3 | 135.7 | 90.5 | 129.3 | 77.6 | 129.3 | 71.1 |
| | | 2 | 142.2 | 90.5 | 142.2 | 93.7 | 135.7 | 53.7 | 113.1 | 90.5 | 142.2 | 74.3 | 100.2 | 74.3 | 100.2 | 90.5 | 139.0 | 77.6 | 132.5 | 74.3 |
| | | 3 | 142.2 | 80.8 | 113.1 | 87.3 | 116.3 | 74.3 | 113.1 | 74.3 | 119.6 | 74.3 | 100.2 | 74.3 | 106.6 | 93.7 | 129.3 | 74.3 | 129.3 | 71.1 |
| | 11 | 1 | 126.0 | 77.6 | 126.0 | 80.8 | 132.5 | 84.0 | 119.6 | 71.1 | 135.7 | 74.3 | 132.5 | 74.3 | 106.6 | 74.3 | 103.4 | 80.8 | 122.8 | 74.3 |
| | | 2 | 119.6 | 74.3 | 126.0 | 74.3 | 135.7 | 80.8 | 122.8 | 71.1 | 132.5 | 61.4 | 145.4 | 74.3 | 90.5 | 74.3 | 126.0 | 77.6 | 119.6 | 74.3 |
| | | 3 | 119.6 | 67.9 | 135.7 | 74.3 | 142.2 | 80.8 | 113.1 | 71.1 | 122.8 | 64.6 | 126.0 | 74.3 | 90.5 | 74.3 | 113.1 | 74.3 | 122.8 | 74.3 |
| | 13 | 1 | 126.0 | 77.6 | 113.1 | 71.1 | 148.7 | 71.1 | 126.0 | 90.5 | 116.3 | 74.3 | 106.6 | 64.6 | 106.6 | 74.3 | 74.3 | 74.3 | 129.3 | 67.9 |
| | | 2 | 119.6 | 67.9 | 116.3 | 71.1 | 122.8 | 67.9 | 129.3 | 77.6 | 119.6 | 71.1 | 106.6 | 64.6 | 87.3 | 77.6 | 64.6 | 74.3 | 126.0 | 74.3 |
| | | 3 | 116.3 | 67.9 | 113.1 | 64.6 | 139.0 | 64.6 | 109.9 | 74.3 | 103.4 | 74.3 | 119.6 | 64.6 | 122.8 | 87.3 | 80.8 | 74.3 | 80.8 | 84.0 |
| 10 | 7 | 1 | 51.7 | 64.6 | 51.7 | 58.2 | 74.3 | 61.4 | 87.3 | 64.6 | 71.1 | 58.2 | 80.8 | 54.9 | 64.6 | 42.0 | 84.0 | 58.2 | 74.3 | 61.4 |
| | | 2 | 74.3 | 58.2 | 54.9 | 48.5 | 71.1 | 61.4 | 80.8 | 64.6 | 74.3 | 61.4 | 77.6 | 61.4 | 61.4 | 51.7 | 77.6 | 61.4 | 64.6 | 58.2 |
| | | 3 | 74.3 | 61.4 | 48.5 | 48.5 | 67.9 | 61.4 | 77.6 | 64.6 | 71.1 | 58.2 | 77.6 | 61.4 | 58.2 | 58.2 | 80.8 | 67.9 | 67.9 | 64.6 |
| | 9 | 1 | 67.9 | 67.9 | 87.3 | 71.1 | 90.5 | 71.1 | 74.3 | 51.7 | 54.9 | 58.2 | 87.3 | 67.9 | 80.8 | 54.9 | 64.6 | 58.2 | 77.6 | 64.6 |
| | | 2 | 71.1 | 64.6 | 71.1 | 74.3 | 90.5 | 64.6 | 71.1 | 54.9 | 61.4 | 61.4 | 71.1 | 67.9 | 71.1 | 58.2 | 58.2 | 58.2 | 84.0 | 67.9 |
| | | 3 | 67.9 | 61.4 | 64.6 | 71.4 | 84.0 | 64.6 | 74.3 | 64.6 | 74.3 | 61.4 | 74.3 | 64.6 | 71.1 | 54.9 | 58.2 | 64.6 | 74.3 | 67.9 |
| | 11 | 1 | 74.3 | 48.5 | 71.1 | 61.4 | 77.6 | 54.9 | 58.2 | 64.6 | 64.6 | 51.7 | 64.6 | 64.6 | 61.4 | 48.5 | 77.6 | 67.9 | 74.3 | 64.6 |
| | | 2 | 61.4 | 51.7 | 74.3 | 61.4 | 74.3 | 51.7 | 48.5 | 67.9 | 67.9 | 51.7 | 64.6 | 61.4 | 64.6 | 51.7 | 84.0 | 74.3 | 67.9 | 71.1 |
| | | 3 | 64.6 | 58.2 | 71.1 | 58.2 | 80.8 | 64.6 | 48.5 | 67.9 | 64.6 | 61.4 | 64.6 | 58.2 | 54.9 | 48.5 | 93.7 | 74.3 | 74.3 | 67.9 |
| | 13 | 1 | 74.3 | 58.2 | 71.1 | 54.9 | 64.6 | 61.4 | 58.2 | 77.6 | 77.6 | 71.1 | 71.1 | 61.4 | 84.0 | 58.2 | 67.9 | 64.6 | 84.0 | 64.6 |
| | | 2 | 74.3 | 58.2 | 77.6 | 64.6 | 58.2 | 61.4 | 58.2 | 62.9 | 67.9 | 71.1 | 64.6 | 67.9 | 71.1 | 54.9 | 74.3 | 58.2 | 77.6 | 61.4 |
| | | 3 | 74.3 | 58.2 | 77.6 | 64.6 | 61.4 | 58.2 | 58.2 | 58.2 | 67.9 | 64.6 | 71.1 | 67.9 | 84.0 | 54.9 | 71.1 | 61.4 | 80.8 | 61.4 |

APPENDIX G

EXTENSION AND FLEXION TORQUE DATA

GENDER : MALE    TORQUE

| SUB. | SIZE | R | SHAPE C EXT. | FLEX. | SHAPE D EXT. | FLEX. | SHAPE Q EXT. | FLEX. | SHAPE T EXT. | FLEX. | SHAPE S EXT. | FLEX. | SHAPE W EXT. | FLEX. | SHAPE X EXT. | FLEX. | SHAPE Y EXT. | FLEX. | SHAPE Z EXT. | FLEX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 0.274 | 0.169 | 0.484 | 0.438 | 0.432 | 0.331 | 0.404 | 0.430 | 0.326 | 0.223 | 0.379 | 0.277 | 0.590 | 0.492 | 0.642 | 0.545 | 0.747 | 0.814 |
|  |  | 2 | 0.274 | 0.169 | 0.484 | 0.438 | 0.432 | 0.331 | 0.484 | 0.384 | 0.379 | 0.277 | 0.379 | 0.277 | 0.590 | 0.492 | 0.642 | 0.599 | 0.747 | 0.707 |
|  |  | 3 | 0.221 | 0.168 | 0.432 | 0.438 | 0.484 | 0.331 | 0.484 | 0.384 | 0.274 | 0.277 | 0.379 | 0.223 | 0.537 | 0.492 | 0.432 | 0.545 | 0.747 | 0.707 |
|  | 9 | 1 | 0.326 | 0.169 | 0.695 | 0.707 | 0.590 | 0.492 | 0.905 | 1.029 | 0.642 | 0.545 | 0.695 | 0.653 | 0.800 | 0.814 | 1.010 | 0.975 | 1.274 | 1.298 |
|  |  | 2 | 0.326 | 0.169 | 0.747 | 0.653 | 0.642 | 0.492 | 0.853 | 0.922 | 0.590 | 0.545 | 0.642 | 0.599 | 0.853 | 0.814 | 1.010 | 1.029 | 1.116 | 1.298 |
|  |  | 3 | 0.274 | 0.169 | 0.695 | 0.707 | 0.537 | 0.492 | 0.800 | 0.922 | 0.484 | 0.545 | 0.642 | 0.653 | 0.958 | 0.868 | 0.905 | 0.922 | 1.063 | 1.244 |
|  | 11 | 1 | 0.432 | 0.277 | 0.905 | 0.922 | 0.747 | 0.707 | 1.221 | 1.190 | 0.747 | 0.599 | 0.800 | 0.814 | 1.063 | 1.137 | 1.274 | 1.566 | 1.010 | 1.727 |
|  |  | 2 | 0.484 | 0.277 | 0.905 | 0.868 | 0.747 | 0.760 | 1.431 | 1.459 | 0.800 | 0.599 | 0.747 | 0.599 | 0.905 | 0.975 | 1.010 | 1.083 | 1.168 | 1.620 |
|  |  | 3 | 0.432 | 0.277 | 0.905 | 0.868 | 0.853 | 0.760 | 1.537 | 1.566 | 0.958 | 0.868 | 0.958 | 1.029 | 1.274 | 1.459 | 1.010 | 1.942 | 1.379 | 1.889 |
|  | 13 | 1 | 0.432 | 0.384 | 0.747 | 1.298 | 1.168 | 1.029 | 1.431 | 1.459 | 1.063 | 0.814 | 1.010 | 0.975 | 1.274 | 1.298 | 1.116 | 1.835 | 1.221 | 2.157 |
|  |  | 2 | 0.537 | 0.384 | 1.063 | 1.244 | 1.274 | 1.029 | 1.431 | 1.405 | 0.853 | 0.760 | 1.168 | 0.975 | 1.221 | 1.137 | 1.116 | 1.781 | 1.379 | 2.049 |
| 2 | 7 | 1 | 0.221 | 0.168 | 0.432 | 0.277 | 0.379 | 0.277 | 0.326 | 0.223 | 0.274 | 0.169 | 0.432 | 0.277 | 0.537 | 0.277 | 0.695 | 0.438 | 0.905 | 0.545 |
|  |  | 2 | 0.221 | 0.168 | 0.484 | 0.277 | 0.432 | 0.277 | 0.326 | 0.331 | 0.274 | 0.169 | 0.432 | 0.277 | 0.537 | 0.331 | 0.642 | 0.438 | 0.905 | 0.599 |
|  |  | 3 | 0.221 | 0.168 | 0.432 | 0.331 | 0.432 | 0.277 | 0.379 | 0.277 | 0.274 | 0.223 | 0.432 | 0.331 | 0.537 | 0.331 | 0.590 | 0.438 | 0.853 | 0.654 |
|  | 9 | 1 | 0.326 | 0.169 | 0.853 | 0.653 | 0.484 | 0.384 | 1.168 | 1.029 | 0.537 | 0.599 | 0.537 | 0.438 | 0.800 | 0.653 | 1.063 | 0.868 | 1.116 | 1.298 |
|  |  | 2 | 0.326 | 0.169 | 0.800 | 0.599 | 0.484 | 0.331 | 0.905 | 1.029 | 0.537 | 0.653 | 0.537 | 0.438 | 0.797 | 0.707 | 0.853 | 0.707 | 1.063 | 1.029 |
|  |  | 3 | 0.326 | 0.169 | 0.695 | 0.599 | 0.484 | 0.385 | 1.010 | 1.029 | 0.800 | 0.492 | 0.537 | 0.438 | 0.905 | 0.653 | 0.853 | 0.868 | 1.063 | 0.975 |
|  | 11 | 1 | 0.326 | 0.277 | 0.958 | 0.707 | 0.695 | 0.384 | 1.589 | 1.405 | 0.642 | 0.492 | 0.905 | 0.707 | 0.958 | 0.653 | 1.221 | 1.244 | 1.326 | 1.459 |
|  |  | 2 | 0.326 | 0.223 | 0.905 | 0.707 | 0.642 | 0.384 | 1.537 | 1.459 | 0.695 | 0.438 | 0.853 | 0.707 | 1.010 | 0.653 | 1.010 | 1.244 | 1.326 | 1.781 |
|  | 13 | 1 | 0.432 | 0.277 | 0.905 | 1.083 | 1.010 | 1.137 | 0.642 | 1.244 | 1.010 | 0.760 | 0.642 | 0.975 | 1.221 | 1.405 | 1.063 | 1.620 | 1.168 | 1.781 |
|  |  | 2 | 0.379 | 0.277 | 0.800 | 1.029 | 0.905 | 1.029 | 0.958 | 0.814 | 0.800 | 0.868 | 0.853 | 0.814 | 1.063 | 1.512 | 1.063 | 1.620 | 1.169 | 1.942 |
|  |  | 3 | 0.379 | 0.277 | 0.484 | 0.331 | 0.958 | 1.029 | 0.326 | 0.298 | 1.010 | 0.760 | 0.853 | 0.814 | 1.221 | 1.512 | 1.063 | 1.620 | 1.221 | 1.791 |
| 3 | 7 | 1 | 0.221 | 0.116 | 0.537 | 0.223 | 0.484 | 0.331 | 0.432 | 0.223 | 0.326 | 0.223 | 0.590 | 0.438 | 0.695 | 0.438 | 0.484 | 0.653 | 0.747 | 0.599 |
|  |  | 2 | 0.221 | 0.116 | 0.484 | 0.223 | 0.537 | 0.277 | 0.432 | 0.223 | 0.326 | 0.223 | 0.537 | 0.438 | 0.642 | 0.545 | 0.432 | 0.653 | 0.747 | 0.653 |
|  |  | 3 | 0.221 | 0.116 | 0.432 | 0.223 | 0.537 | 0.331 | 0.379 | 0.277 | 0.379 | 0.223 | 0.537 | 0.384 | 0.590 | 0.599 | 0.432 | 1.029 | 0.747 | 0.707 |
|  | 9 | 1 | 0.274 | 0.169 | 0.747 | 0.545 | 0.642 | 0.223 | 1.160 | 1.029 | 0.484 | 0.492 | 0.853 | 0.653 | 0.800 | 0.760 | 0.537 | 1.029 | 0.958 | 1.031 |
|  |  | 2 | 0.274 | 0.169 | 0.695 | 0.384 | 0.642 | 0.223 | 1.116 | 1.029 | 0.484 | 0.545 | 0.800 | 0.707 | 0.642 | 0.760 | 0.642 | 1.029 | 0.905 | 1.137 |
|  |  | 3 | 0.274 | 0.169 | 0.537 | 0.492 | 0.590 | 0.331 | 1.010 | 0.975 | 0.484 | 0.438 | 0.800 | 0.707 | 0.695 | 0.814 | 0.642 | 1.029 | 0.800 | 1.137 |
|  | 11 | 1 | 0.432 | 0.223 | 0.695 | 0.760 | 0.747 | 0.492 | 1.379 | 0.975 | 0.537 | 0.599 | 0.853 | 0.707 | 0.853 | 0.922 | 1.010 | 1.190 | 0.958 | 1.137 |
|  |  | 2 | 0.432 | 0.223 | 0.695 | 0.653 | 0.747 | 0.599 | 1.221 | 1.029 | 0.537 | 0.492 | 0.800 | 0.653 | 0.905 | 1.029 | 0.905 | 1.137 | 0.905 | 1.244 |
|  |  | 3 | 0.432 | 0.223 | 0.695 | 0.760 | 0.800 | 0.545 | 1.431 | 1.029 | 0.537 | 0.438 | 0.853 | 0.653 | 0.905 | 1.029 | 0.958 | 1.137 | 0.853 | 1.137 |
|  | 13 | 1 | 0.379 | 0.169 | 0.905 | 0.760 | 0.695 | 0.814 | 1.063 | 1.190 | 0.958 | 0.545 | 1.326 | 1.083 | 1.379 | 1.083 | 0.800 | 1.244 | 0.537 | 1.674 |
|  |  | 2 | 0.379 | 0.223 | 1.010 | 0.760 | 0.695 | 0.814 | 1.168 | 1.244 | 0.800 | 0.599 | 1.168 | 1.029 | 1.326 | 0.975 | 0.853 | 1.137 | 0.590 | 1.674 |
|  |  | 3 | 0.379 | 0.223 | 1.010 | 0.707 | 0.642 | 0.760 | 1.063 | 1.298 | 0.905 | 0.599 | 1.168 | 0.975 | 1.326 | 0.975 | 0.800 | 1.083 | 0.537 | 1.727 |
| 4 | 7 | 1 | 0.221 | 0.168 | 0.432 | 0.384 | 0.379 | 0.331 | 0.319 | 0.331 | 0.326 | 0.169 | 0.432 | 0.384 | 0.590 | 0.492 | 0.642 | 0.707 | 0.747 | 0.814 |
|  |  | 2 | 0.221 | 0.116 | 0.432 | 0.384 | 0.379 | 0.331 | 0.432 | 0.331 | 0.274 | 0.169 | 0.432 | 0.384 | 0.484 | 0.492 | 0.484 | 0.707 | 0.642 | 0.653 |
|  |  | 3 | 0.221 | 0.169 | 0.379 | 0.384 | 0.379 | 0.331 | 0.326 | 0.331 | 0.274 | 0.169 | 0.379 | 0.384 | 0.537 | 0.438 | 0.484 | 0.853 | 0.653 | 0.653 |
|  | 9 | 1 | 0.274 | 0.169 | 0.747 | 0.545 | 0.537 | 0.438 | 0.853 | 0.760 | 0.590 | 0.331 | 0.537 | 0.492 | 0.958 | 0.922 | 0.747 | 0.868 | 1.010 | 1.190 |
|  |  | 2 | 0.274 | 0.277 | 0.642 | 0.492 | 0.484 | 0.384 | 0.642 | 0.760 | 0.537 | 0.384 | 0.537 | 0.430 | 0.905 | 0.868 | 0.800 | 0.760 | 0.958 | 1.029 |
|  |  | 3 | 0.274 | 0.223 | 0.800 | 0.599 | 0.642 | 0.545 | 0.642 | 0.707 | 0.484 | 0.384 | 0.537 | 0.492 | 0.853 | 0.814 | 0.800 | 0.707 | 1.010 | 1.137 |
|  | 11 | 1 | 0.326 | 0.223 | 0.747 | 0.707 | 0.590 | 0.545 | 0.905 | 0.922 | 0.484 | 0.438 | 0.800 | 0.653 | 0.853 | 1.029 | 0.800 | 1.029 | 1.168 | 1.190 |
|  |  | 2 | 0.326 | 0.223 | 0.695 | 0.707 | 0.537 | 0.492 | 0.747 | 0.863 | 0.484 | 0.384 | 0.695 | 0.599 | 0.800 | 0.975 | 0.747 | 1.083 | 1.116 | 1.001 |
|  | 13 | 1 | 0.379 | 0.277 | 0.853 | 0.760 | 1.010 | 0.868 | 1.274 | 0.922 | 0.747 | 0.707 | 0.800 | 0.707 | 1.221 | 1.190 | 1.063 | 1.244 | 1.274 | 1.620 |
|  |  | 2 | 0.484 | 0.223 | 0.800 | 0.707 | 0.958 | 0.760 | 1.168 | 0.922 | 0.642 | 0.599 | 0.747 | 0.653 | 1.221 | 1.029 | 1.063 | 1.405 | 1.326 | 1.566 |
|  |  | 3 | 0.379 | 0.277 | 0.800 | 0.707 | 0.958 | 0.814 | 1.010 | 0.868 | 0.695 | 0.599 | 0.958 | 0.707 | 1.116 | 1.029 | 1.010 | 1.298 | 1.274 | 1.512 |
| 5 | 7 | 1 | 0.274 | 0.169 | 0.484 | 0.331 | 0.432 | 0.331 | 0.379 | 0.331 | 0.432 | 0.277 | 0.484 | 0.331 | 0.695 | 0.492 | 0.642 | 0.492 | 0.853 | 0.707 |
|  |  | 2 | 0.274 | 0.169 | 0.484 | 0.331 | 0.432 | 0.331 | 0.379 | 0.331 | 0.379 | 0.223 | 0.484 | 0.277 | 0.590 | 0.545 | 0.642 | 0.492 | 0.905 | 0.760 |
|  |  | 3 | 0.274 | 0.223 | 0.695 | 0.707 | 0.642 | 0.384 | 0.905 | 0.707 | 0.642 | 0.492 | 0.747 | 0.599 | 0.905 | 0.922 | 1.221 | 1.190 | 1.168 | 0.922 |
|  | 9 | 1 | 0.274 | 0.223 | 0.695 | 0.707 | 0.590 | 0.438 | 0.853 | 0.599 | 0.695 | 0.492 | 0.800 | 0.545 | 0.800 | 0.922 | 1.063 | 1.083 | 1.063 | 1.137 |
|  |  | 2 | 0.326 | 0.169 | 0.695 | 0.653 | 0.747 | 0.384 | 0.853 | 0.599 | 0.695 | 0.492 | 0.695 | 0.868 | 1.116 | 1.190 | 0.853 | 1.190 |  |  |
|  | 11 | 1 | 0.379 | 0.223 | 0.958 | 0.707 | 0.905 | 0.760 | 0.747 | 1.083 | 1.116 | 1.029 | 1.010 | 0.760 | 1.168 | 1.083 | 1.431 | 1.298 | 0.379 | 1.190 |
|  |  | 2 | 0.379 | 0.277 | 0.958 | 0.760 | 0.853 | 0.653 | 1.168 | 1.083 | 1.010 | 0.922 | 1.010 | 0.707 | 1.221 | 1.083 | 1.379 | 1.351 | 1.326 | 1.298 |
|  |  | 3 | 0.432 | 0.223 | 0.958 | 0.814 | 0.905 | 0.814 | 1.063 | 0.975 | 1.010 | 0.922 | 0.958 | 0.760 | 1.326 | 1.405 | 1.326 | 1.190 | 1.293 | 1.620 |
|  | 13 | 1 | 0.537 | 0.384 | 1.005 | 0.868 | 0.958 | 1.083 | 1.221 | 1.298 | 1.379 | 0.922 | 1.484 | 1.351 | 1.326 | 1.405 | 1.557 | 1.566 | 1.589 | 1.674 |
|  |  | 2 | 0.642 | 0.384 | 1.116 | 0.707 | 0.958 | 1.029 | 1.326 | 1.405 | 1.168 | 1.029 | 1.484 | 1.351 | 1.274 | 1.459 | 1.537 | 1.566 | 1.589 | 1.674 |
|  |  | 3 | 0.537 | 0.438 | 1.010 | 0.814 | 0.853 | 1.029 | 1.379 | 1.405 | 1.116 | 0.922 | 1.537 | 1.351 | 1.274 | 1.512 | 1.326 | 1.459 | 1.537 | 1.727 |

(TO BE CONTINUED)

| SUB. | SIZE | R | SHAPE C EXT. | FLEX. | SHAPE D EXT. | FLEX. | SHAPE Q EXT. | FLEX. | SHAPE T EXT. | FLEX. | SHAPE S EXT. | FLEX. | SHAPE W EXT. | FLEX. | SHAPE X EXT. | FLEX. | SHAPE Y EXT. | FLEX. | SHAPE Z EXT. | FLEX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 1 | 0.221 | 0.169 | 0.537 | 0.223 | 0.432 | 0.223 | 0.379 | 0.331 | 0.326 | 0.169 | 0.432 | 0.223 | 0.590 | 0.384 | 0.590 | 0.492 | 0.695 | 0.545 |
|  |  | 2 | 0.274 | 0.169 | 0.432 | 0.277 | 0.432 | 0.277 | 0.432 | 0.331 | 0.326 | 0.223 | 0.379 | 0.277 | 0.590 | 0.384 | 0.537 | 0.438 | 0.590 | 0.492 |
|  |  | 3 | 0.274 | 0.169 | 0.484 | 0.277 | 0.432 | 0.223 | 0.379 | 0.384 | 0.537 | 0.438 | 0.695 | 0.384 | 0.800 | 0.599 | 1.063 | 0.760 | 0.605 | 0.975 |
|  | 9 | 1 | 0.326 | 0.169 | 0.590 | 0.438 | 0.537 | 0.331 | 0.747 | 0.707 | 0.590 | 0.438 | 0.642 | 0.438 | 0.800 | 0.599 | 1.063 | 0.814 | 1.063 | 0.922 |
|  |  | 2 | 0.326 | 0.223 | 0.590 | 0.438 | 0.537 | 0.438 | 0.695 | 0.760 | 0.642 | 0.384 | 0.695 | 0.438 | 0.747 | 0.545 | 1.063 | 0.814 | 1.063 | 1.351 |
|  |  | 3 | 0.379 | 0.223 | 0.905 | 0.760 | 0.695 | 0.653 | 0.800 | 0.545 | 0.800 | 0.653 | 1.010 | 0.922 | 1.221 | 1.244 | 0.958 | 1.083 | 0.958 | 1.296 |
|  | 11 | 1 | 0.379 | 0.223 | 0.905 | 0.707 | 0.747 | 0.653 | 1.010 | 1.405 | 0.853 | 0.653 | 1.010 | 0.922 | 1.063 | 1.244 | 0.958 | 1.083 | 0.958 | 1.296 |
|  |  | 2 | 0.379 | 0.277 | 0.958 | 0.707 | 0.747 | 0.653 | 1.063 | 1.137 | 0.800 | 0.438 | 0.905 | 0.922 | 1.168 | 1.244 | 1.010 | 1.298 | 0.958 | 1.296 |
|  | 13 | 1 | 0.432 | 0.277 | 0.905 | 0.975 | 0.747 | 0.545 | 1.274 | 1.190 | 0.695 | 0.545 | 0.905 | 0.707 | 0.853 | 0.868 | 0.958 | 1.512 | 1.010 | 1.454 |
|  |  | 2 | 0.484 | 0.277 | 0.853 | 0.922 | 0.853 | 0.653 | 1.326 | 1.137 | 0.642 | 0.599 | 0.800 | 0.653 | 0.905 | 1.029 | 0.905 | 1.459 | 0.800 | 1.351 |
| 7 | 7 | 1 | 0.274 | 0.168 | 0.537 | 0.492 | 0.432 | 0.277 | 0.484 | 0.277 | 0.274 | 0.223 | 0.537 | 0.331 | 0.642 | 0.492 | 0.590 | 0.492 | 0.800 | 0.545 |
|  |  | 2 | 0.274 | 0.169 | 0.484 | 0.384 | 0.484 | 0.277 | 0.432 | 0.277 | 0.274 | 0.223 | 0.484 | 0.331 | 0.590 | 0.438 | 0.642 | 0.545 | 0.853 | 0.545 |
|  |  | 3 | 0.221 | 0.169 | 0.537 | 0.438 | 0.484 | 0.223 | 0.905 | 0.653 | 0.537 | 0.351 | 0.484 | 0.492 | 0.747 | 0.599 | 1.010 | 0.922 | 0.853 | 0.975 |
|  | 9 | 1 | 0.379 | 0.223 | 0.747 | 0.707 | 0.484 | 0.384 | 0.905 | 0.653 | 0.537 | 0.384 | 0.642 | 0.599 | 0.747 | 0.599 | 0.958 | 0.868 | 0.958 | 0.975 |
|  |  | 2 | 0.379 | 0.223 | 0.747 | 0.653 | 0.537 | 0.384 | 0.853 | 0.653 | 0.590 | 0.331 | 0.642 | 0.492 | 0.747 | 0.492 | 0.958 | 0.922 | 0.853 | 0.922 |
|  |  | 3 | 0.379 | 0.277 | 0.747 | 0.653 | 0.905 | 0.868 | 0.800 | 0.492 | 1.484 | 1.351 | 0.800 | 0.599 | 1.168 | 1.137 | 1.221 | 1.351 | 1.373 | 1.244 |
|  | 11 | 1 | 0.379 | 0.277 | 0.905 | 0.760 | 0.695 | 0.599 | 1.326 | 1.298 | 0.747 | 0.599 | 1.010 | 0.760 | 1.010 | 1.029 | 1.274 | 1.298 | 1.221 | 1.137 |
|  |  | 2 | 0.379 | 0.277 | 0.853 | 0.760 | 0.695 | 0.599 | 1.274 | 1.244 | 0.747 | 0.599 | 1.053 | 0.760 | 1.010 | 1.029 | 1.158 | 1.351 | 1.274 | 1.137 |
|  | 13 | 1 | 0.412 | 0.331 | 0.905 | 0.922 | 1.010 | 0.599 | 2.326 | 1.190 | 1.168 | 1.083 | 1.063 | 0.922 | 1.116 | 1.351 | 1.326 | 1.512 | 1.326 | 1.512 |
|  |  | 2 | 0.432 | 0.384 | 0.800 | 0.922 | 1.063 | 0.868 | 2.063 | 1.298 | 1.168 | 1.083 | 1.063 | 0.975 | 1.274 | 1.190 | 1.326 | 1.298 | 1.168 | 1.674 |
|  |  | 3 | 0.484 | 0.384 | 1.010 | 0.868 | 0.958 | 0.814 | 1.168 | 1.137 | 1.116 | 1.083 | 1.063 | 0.975 | 1.326 | 1.190 | 1.221 | 1.405 | 1.379 | 1.402 |
| 8 | 7 | 1 | 0.169 | 0.221 | 0.331 | 0.379 | 0.277 | 0.379 | 0.384 | 0.379 | 0.223 | 0.274 | 0.277 | 0.432 | 0.331 | 0.432 | 0.438 | 0.590 | 0.545 | 0.695 |
|  |  | 2 | 0.169 | 0.221 | 0.331 | 0.326 | 0.277 | 0.379 | 0.384 | 0.379 | 0.223 | 0.274 | 0.331 | 0.379 | 0.599 | 0.747 | 0.538 | 0.905 | 0.545 | 0.642 |
|  | 9 | 1 | 0.223 | 0.274 | 0.384 | 0.590 | 0.438 | 0.484 | 0.438 | 0.747 | 0.384 | 0.484 | 0.492 | 0.537 | 0.599 | 0.695 | 0.599 | 0.747 | 0.814 | 1.010 |
|  |  | 2 | 0.223 | 0.274 | 0.492 | 0.642 | 0.438 | 0.484 | 0.438 | 0.747 | 0.438 | 0.432 | 0.492 | 0.537 | 0.599 | 0.695 | 0.599 | 0.747 | 0.814 | 0.905 |
|  |  | 3 | 0.223 | 0.274 | 0.545 | 0.695 | 0.438 | 0.642 | 0.438 | 0.432 | 0.545 | 0.695 | 0.868 | 0.695 | 0.707 | 1.010 | 0.760 | 1.326 | 0.975 | 1.116 |
|  | 11 | 1 | 0.223 | 0.274 | 0.545 | 0.747 | 0.438 | 0.590 | 0.438 | 0.747 | 0.492 | 0.747 | 0.760 | 0.590 | 0.599 | 0.853 | 0.922 | 1.326 | 0.868 | 1.116 |
|  |  | 2 | 0.223 | 0.274 | 0.545 | 0.747 | 0.384 | 0.432 | 0.438 | 0.747 | 0.707 | 0.800 | 0.707 | 0.800 | 0.922 | 1.326 | 0.922 | 1.168 |  |  |
|  | 13 | 1 | 0.277 | 0.326 | 0.545 | 0.695 | 0.599 | 0.958 | 1.083 | 0.958 | 0.545 | 0.432 | 0.653 | 0.958 | 0.922 | 1.010 | 0.975 | 1.116 | 0.814 | 1.431 |
|  |  | 2 | 0.277 | 0.326 | 0.599 | 0.695 | 0.760 | 0.905 | 0.922 | 0.958 | 0.492 | 0.537 | 0.653 | 0.905 | 0.868 | 1.221 | 0.760 | 1.274 | 0.814 | 1.379 |
| 9 | 7 | 1 | 0.221 | 0.169 | 0.274 | 0.331 | 0.379 | 0.223 | 0.379 | 0.223 | 0.274 | 0.169 | 0.379 | 0.223 | 0.537 | 0.492 | 0.537 | 0.384 | 0.642 | 0.545 |
|  |  | 2 | 0.221 | 0.116 | 0.326 | 0.331 | 0.379 | 0.223 | 0.379 | 0.223 | 0.326 | 0.223 | 0.379 | 0.223 | 0.537 | 0.438 | 0.590 | 0.384 | 0.537 | 0.642 |
|  | 9 | 1 | 0.326 | 0.116 | 0.590 | 0.277 | 0.537 | 0.331 | 0.747 | 0.545 | 0.432 | 0.384 | 0.537 | 0.438 | 0.747 | 0.707 | 0.800 | 0.707 | 0.800 | 0.760 |
|  |  | 2 | 0.326 | 0.169 | 0.695 | 0.331 | 0.537 | 0.384 | 0.695 | 0.492 | 0.379 | 0.331 | 0.484 | 0.384 | 0.642 | 0.653 | 0.747 | 0.599 | 0.642 | 0.863 |
|  |  | 3 | 0.326 | 0.169 | 0.695 | 0.384 | 0.590 | 0.331 | 0.432 | 0.438 | 0.432 | 0.331 | 0.590 | 0.384 | 0.747 | 0.653 | 0.800 | 0.853 | 0.800 | 0.760 |
|  | 11 | 1 | 0.326 | 0.169 | 0.695 | 0.384 | 0.642 | 0.384 | 1.168 | 1.029 | 0.642 | 0.492 | 0.800 | 0.760 | 0.853 | 0.707 | 0.958 | 0.868 | 0.695 | 1.029 |
|  |  | 2 | 0.326 | 0.169 | 0.747 | 0.438 | 0.590 | 0.384 | 1.063 | 0.922 | 0.590 | 0.438 | 0.800 | 0.814 | 0.800 | 0.760 | 1.010 | 0.868 | 0.695 | 1.029 |
|  | 13 | 1 | 0.379 | 0.384 | 0.800 | 0.492 | 0.853 | 0.707 | 1.537 | 1.137 | 0.800 | 0.653 | 1.053 | 0.975 | 1.063 | 1.137 | 1.063 | 1.190 | 1.221 | 1.351 |
|  |  | 2 | 0.379 | 0.277 | 0.642 | 0.707 | 0.853 | 0.707 | 1.589 | 0.922 | 0.695 | 0.653 | 1.063 | 0.760 | 1.010 | 1.083 | 0.958 | 1.083 | 1.168 | 1.298 |
|  |  | 3 | 0.379 | 0.277 | 0.695 | 0.599 | 0.800 | 0.707 | 1.431 | 1.083 | 0.853 | 0.653 | 1.010 | 0.868 | 1.010 | 1.029 | 1.010 | 1.083 | 1.168 | 1.298 |
| 10 | 7 | 1 | 0.274 | 0.223 | 0.379 | 0.384 | 0.432 | 0.331 | 0.432 | 0.331 | 0.274 | 0.223 | 0.432 | 0.384 | 0.537 | 0.492 | 0.642 | 0.545 | 0.800 | 0.707 |
|  |  | 2 | 0.274 | 0.169 | 0.379 | 0.384 | 0.432 | 0.331 | 0.379 | 0.331 | 0.326 | 0.223 | 0.432 | 0.331 | 0.537 | 0.438 | 0.590 | 0.438 | 0.747 | 0.653 |
|  | 9 | 1 | 0.326 | 0.223 | 0.695 | 0.760 | 0.590 | 0.384 | 0.537 | 0.653 | 0.747 | 0.384 | 0.747 | 0.599 | 0.747 | 0.814 | 1.063 | 0.814 | 0.958 | 1.298 |
|  |  | 2 | 0.326 | 0.277 | 0.695 | 0.707 | 0.537 | 0.438 | 0.747 | 0.545 | 0.590 | 0.384 | 0.642 | 0.492 | 0.642 | 0.760 | 1.010 | 0.814 | 1.168 | 1.190 |
|  |  | 3 | 0.432 | 0.223 | 0.695 | 0.653 | 0.537 | 0.331 | 0.695 | 0.599 | 0.642 | 0.438 | 0.695 | 0.599 | 0.800 | 0.707 | 1.274 | 0.814 | 1.116 | 1.190 |
|  | 11 | 1 | 0.484 | 0.277 | 0.905 | 0.975 | 0.853 | 0.868 | 1.274 | 0.975 | 0.747 | 0.868 | 1.116 | 1.137 | 1.168 | 1.137 | 1.274 | 1.674 | 1.464 | 2.050 |
|  |  | 2 | 0.484 | 0.223 | 0.905 | 0.868 | 0.590 | 0.814 | 1.326 | 1.190 | 0.642 | 0.814 | 1.010 | 1.137 | 1.116 | 0.975 | 1.274 | 1.566 | 1.484 | 1.781 |
|  |  | 3 | 0.484 | 0.277 | 0.747 | 0.814 | 0.800 | 0.814 | 1.326 | 1.083 | 0.695 | 0.707 | 0.905 | 1.083 | 1.063 | 1.029 | 1.221 | 1.512 | 1.484 | 1.781 |
|  | 13 | 1 | 0.484 | 0.438 | 1.168 | 0.975 | 1.168 | 1.083 | 1.589 | 1.620 | 1.063 | 1.029 | 1.221 | 1.459 | 1.589 | 1.727 | 1.484 | 1.674 | 1.852 | 1.351 |
|  |  | 2 | 0.537 | 0.438 | 1.063 | 1.029 | 1.274 | 1.137 | 1.589 | 1.459 | 1.010 | 0.975 | 1.168 | 1.405 | 1.431 | 1.512 | 1.484 | 1.566 | 1.747 | 1.459 |
|  |  | 3 | 0.537 | 0.492 | 1.274 | 0.975 | 1.168 | 1.244 | 1.642 | 1.459 | 1.010 | 1.083 | 1.221 | 1.405 | 1.379 | 1.405 | 1.379 | 1.459 | 1.642 | 1.566 |

GENDER : FEMALE    TORQUE

| SUB. | SIZE | R | SHAPE C EXT. | SHAPE C FLEX. | SHAPE D EXT. | SHAPE D FLEX. | SHAPE O EXT. | SHAPE O FLEX. | SHAPE T EXT. | SHAPE T FLEX. | SHAPE S EXT. | SHAPE S FLEX. | SHAPE W EXT. | SHAPE W FLEX. | SHAPE X EXT. | SHAPE X FLEX. | SHAPE Y EXT. | SHAPE Y FLEX. | SHAPE Z EXT. | SHAPE Z FLEX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 1 | 0.221 | 0.116 | 0.274 | 0.331 | 0.379 | 0.277 | 0.379 | 0.277 | 0.274 | 0.169 | 0.432 | 0.331 | 0.484 | 0.384 | 0.590 | 0.223 | 0.484 | 0.331 |
|  |  | 2 | 0.221 | 0.116 | 0.274 | 0.277 | 0.379 | 0.223 | 0.432 | 0.277 | 0.274 | 0.169 | 0.432 | 0.277 | 0.432 | 0.331 | 0.537 | 0.223 | 0.537 | 0.438 |
|  |  | 3 | 0.221 | 0.116 | 0.274 | 0.277 | 0.326 | 0.223 | 0.379 | 0.277 | 0.274 | 0.169 | 0.379 | 0.277 | 0.432 | 0.331 | 0.537 | 0.223 | 0.537 | 0.438 |
|  | 9 | 1 | 0.326 | 0.169 | 0.590 | 0.492 | 0.484 | 0.223 | 0.590 | 0.384 | 0.537 | 0.384 | 0.642 | 0.331 | 0.590 | 0.599 | 0.590 | 0.492 | 0.800 | 0.760 |
|  |  | 2 | 0.326 | 0.169 | 0.590 | 0.492 | 0.432 | 0.223 | 0.642 | 0.384 | 0.537 | 0.384 | 0.537 | 0.331 | 0.590 | 0.599 | 0.590 | 0.545 | 0.800 | 0.760 |
|  |  | 3 | 0.274 | 0.169 | 0.590 | 0.492 | 0.484 | 0.277 | 0.537 | 0.384 | 0.484 | 0.331 | 0.590 | 0.331 | 0.695 | 0.599 | 0.642 | 0.545 | 0.800 | 0.814 |
|  | 11 | 1 | 0.274 | 0.223 | 0.590 | 0.438 | 0.432 | 0.223 | 0.747 | 0.707 | 0.537 | 0.599 | 0.747 | 0.653 | 0.695 | 0.814 | 0.695 | 0.868 | 0.695 | 0.922 |
|  |  | 2 | 0.274 | 0.169 | 0.590 | 0.492 | 0.432 | 0.277 | 0.747 | 0.760 | 0.642 | 0.599 | 0.695 | 0.707 | 0.695 | 0.814 | 0.747 | 0.922 | 0.747 | 0.922 |
|  |  | 3 | 0.274 | 0.223 | 0.537 | 0.384 | 0.432 | 0.223 | 0.747 | 0.868 | 0.537 | 0.599 | 0.642 | 0.707 | 0.853 | 0.814 | 0.695 | 0.868 | 0.695 | 0.975 |
|  | 13 | 1 | 0.274 | 0.277 | 0.590 | 0.438 | 0.695 | 0.653 | 0.590 | 0.707 | 0.642 | 0.545 | 0.590 | 0.599 | 0.484 | 0.384 | 0.274 | 0.868 | 0.590 | 1.137 |
|  |  | 2 | 0.326 | 0.223 | 0.484 | 0.492 | 0.747 | 0.653 | 0.642 | 0.707 | 0.642 | 0.492 | 0.484 | 0.653 | 0.379 | 0.277 | 0.326 | 0.922 | 0.484 | 1.137 |
|  |  | 3 | 0.274 | 0.223 | 0.537 | 0.438 | 0.642 | 0.599 | 0.590 | 0.707 | 0.695 | 0.599 | 0.537 | 0.545 | 0.379 | 0.277 | 0.537 | 0.922 | 0.537 | 1.083 |
| 2 | 7 | 1 | 0.221 | 0.169 | 0.432 | 0.331 | 0.484 | 0.277 | 0.379 | 0.277 | 0.326 | 0.223 | 0.432 | 0.331 | 0.432 | 0.331 | 0.537 | 0.492 | 0.537 | 0.438 |
|  |  | 2 | 0.221 | 0.116 | 0.432 | 0.331 | 0.432 | 0.331 | 0.379 | 0.223 | 0.274 | 0.223 | 0.379 | 0.277 | 0.432 | 0.331 | 0.484 | 0.438 | 0.537 | 0.438 |
|  |  | 3 | 0.221 | 0.169 | 0.379 | 0.331 | 0.432 | 0.277 | 0.379 | 0.277 | 0.274 | 0.223 | 0.379 | 0.223 | 0.432 | 0.277 | 0.484 | 0.438 | 0.537 | 0.438 |
|  | 9 | 1 | 0.221 | 0.169 | 0.537 | 0.545 | 0.484 | 0.384 | 0.590 | 0.545 | 0.432 | 0.331 | 0.537 | 0.545 | 0.642 | 0.653 | 0.747 | 0.545 | 0.800 | 0.922 |
|  |  | 2 | 0.221 | 0.169 | 0.484 | 0.492 | 0.432 | 0.384 | 0.642 | 0.545 | 0.432 | 0.277 | 0.537 | 0.492 | 0.484 | 0.599 | 0.695 | 0.599 | 0.853 | 0.868 |
|  |  | 3 | 0.274 | 0.169 | 0.484 | 0.438 | 0.432 | 0.384 | 0.590 | 0.492 | 0.432 | 0.277 | 0.537 | 0.545 | 0.642 | 0.599 | 0.747 | 0.599 | 0.905 | 0.868 |
|  | 11 | 1 | 0.326 | 0.223 | 0.642 | 0.653 | 0.642 | 0.545 | 0.800 | 0.707 | 0.590 | 0.599 | 0.642 | 0.814 | 0.747 | 0.492 | 0.747 | 1.190 | 0.853 | 1.137 |
|  |  | 2 | 0.274 | 0.169 | 0.590 | 0.653 | 0.590 | 0.492 | 0.905 | 0.653 | 0.590 | 0.599 | 0.642 | 0.814 | 0.747 | 0.545 | 0.747 | 0.975 | 0.695 | 1.029 |
|  |  | 3 | 0.274 | 0.169 | 0.590 | 0.653 | 0.537 | 0.492 | 0.695 | 0.653 | 0.642 | 0.599 | 0.590 | 0.760 | 0.747 | 0.438 | 0.747 | 1.029 | 0.800 | 1.029 |
|  | 13 | 1 | 0.274 | 0.223 | 0.590 | 0.707 | 0.695 | 0.653 | 0.958 | 0.922 | 0.747 | 0.599 | 0.537 | 0.707 | 0.800 | 0.975 | 0.853 | 1.083 | 0.905 | 0.814 |
|  |  | 2 | 0.326 | 0.277 | 0.642 | 0.599 | 0.590 | 0.599 | 0.905 | 0.922 | 0.747 | 0.545 | 0.595 | 0.599 | 0.747 | 0.975 | 0.800 | 1.029 | 0.800 | 1.244 |
|  |  | 3 | 0.274 | 0.223 | 0.642 | 0.599 | 0.590 | 0.545 | 0.958 | 0.922 | 0.747 | 0.599 | 0.853 | 0.707 | 0.800 | 0.975 | 0.800 | 1.083 | 0.747 | 1.190 |
| 3 | 7 | 1 | 0.274 | 0.116 | 0.274 | 0.277 | 0.326 | 0.277 | 0.379 | 0.223 | 0.326 | 0.277 | 0.379 | 0.384 | 0.432 | 0.331 | 0.484 | 0.331 | 0.537 | 0.653 |
|  |  | 2 | 0.221 | 0.116 | 0.221 | 0.277 | 0.379 | 0.223 | 0.326 | 0.223 | 0.326 | 0.223 | 0.432 | 0.331 | 0.432 | 0.331 | 0.484 | 0.384 | 0.484 | 0.438 |
|  |  | 3 | 0.221 | 0.116 | 0.274 | 0.223 | 0.379 | 0.223 | 0.432 | 0.277 | 0.379 | 0.223 | 0.432 | 0.384 | 0.432 | 0.331 | 0.537 | 0.438 | 0.537 | 0.492 |
|  | 9 | 1 | 0.274 | 0.169 | 0.537 | 0.384 | 0.379 | 0.331 | 0.484 | 0.331 | 0.537 | 0.545 | 0.590 | 0.599 | 0.590 | 0.653 | 0.590 | 0.922 | 0.747 | 0.760 |
|  |  | 2 | 0.274 | 0.169 | 0.590 | 0.331 | 0.484 | 0.384 | 0.537 | 0.331 | 0.484 | 0.492 | 0.642 | 0.545 | 0.642 | 0.599 | 0.537 | 0.814 | 0.642 | 0.653 |
|  |  | 3 | 0.274 | 0.169 | 0.537 | 0.331 | 0.484 | 0.331 | 0.590 | 0.384 | 0.537 | 0.438 | 0.590 | 0.545 | 0.695 | 0.707 | 0.537 | 0.760 | 0.747 | 0.653 |
|  | 11 | 1 | 0.274 | 0.223 | 0.642 | 0.653 | 0.484 | 0.384 | 1.116 | 0.814 | 0.537 | 0.331 | 0.695 | 0.599 | 0.537 | 0.868 | 0.747 | 0.760 | 0.800 | 1.083 |
|  |  | 2 | 0.274 | 0.169 | 0.747 | 0.599 | 0.484 | 0.438 | 1.010 | 0.760 | 0.537 | 0.438 | 0.695 | 0.653 | 0.695 | 0.922 | 0.695 | 0.868 | 0.590 | 1.083 |
|  |  | 3 | 0.326 | 0.169 | 0.747 | 0.653 | 0.379 | 0.438 | 0.800 | 0.653 | 0.484 | 0.653 | 0.642 | 0.653 | 0.695 | 0.760 | 0.747 | 0.653 | 0.695 | 1.029 |
|  | 13 | 1 | 0.326 | 0.223 | 0.326 | 0.599 | 0.853 | 0.599 | 0.695 | 0.653 | 0.590 | 0.492 | 0.695 | 0.545 | 0.853 | 0.760 | 0.800 | 0.760 | 0.853 | 0.868 |
|  |  | 2 | 0.326 | 0.223 | 0.432 | 0.599 | 0.642 | 0.707 | 0.747 | 0.868 | 0.590 | 0.653 | 0.747 | 0.545 | 0.695 | 0.814 | 0.800 | 0.814 | 0.695 | 0.922 |
|  |  | 3 | 0.326 | 0.223 | 0.432 | 0.599 | 0.642 | 0.599 | 0.695 | 0.868 | 0.747 | 0.599 | 0.695 | 0.492 | 0.695 | 0.868 | 0.695 | 0.814 | 0.747 | 0.868 |
| 4 | 7 | 1 | 0.221 | 0.169 | 0.432 | 0.277 | 0.432 | 0.277 | 0.274 | 0.223 | 0.274 | 0.169 | 0.432 | 0.277 | 0.432 | 0.277 | 0.642 | 0.438 | 0.747 | 0.438 |
|  |  | 2 | 0.221 | 0.116 | 0.432 | 0.223 | 0.379 | 0.277 | 0.326 | 0.277 | 0.326 | 0.223 | 0.432 | 0.277 | 0.379 | 0.331 | 0.590 | 0.438 | 0.484 | 0.438 |
|  |  | 3 | 0.221 | 0.116 | 0.379 | 0.277 | 0.274 | 0.277 | 0.274 | 0.223 | 0.326 | 0.223 | 0.379 | 0.277 | 0.432 | 0.277 | 0.590 | 0.492 | 0.432 | 0.438 |
|  | 9 | 1 | 0.274 | 0.169 | 0.590 | 0.492 | 0.484 | 0.384 | 0.484 | 0.492 | 0.432 | 0.384 | 0.695 | 0.384 | 0.642 | 0.545 | 0.695 | 0.438 | 0.800 | 0.868 |
|  |  | 2 | 0.274 | 0.223 | 0.537 | 0.438 | 0.484 | 0.384 | 0.537 | 0.545 | 0.432 | 0.331 | 0.484 | 0.384 | 0.695 | 0.545 | 0.853 | 0.331 | 0.800 | 0.653 |
|  |  | 3 | 0.274 | 0.169 | 0.537 | 0.545 | 0.537 | 0.384 | 0.537 | 0.492 | 0.379 | 0.331 | 0.537 | 0.438 | 0.695 | 0.492 | 0.642 | 0.384 | 0.958 | 0.707 |
|  | 11 | 1 | 0.274 | 0.223 | 0.484 | 0.653 | 0.590 | 0.438 | 0.958 | 0.975 | 0.642 | 0.438 | 0.800 | 0.922 | 0.958 | 0.707 | 0.905 | 0.975 | 1.116 | 0.975 |
|  |  | 2 | 0.326 | 0.223 | 0.537 | 0.653 | 0.537 | 0.331 | 1.116 | 0.760 | 0.747 | 0.438 | 0.800 | 0.868 | 1.010 | 0.707 | 0.905 | 1.029 | 1.063 | 0.922 |
|  |  | 3 | 0.326 | 0.223 | 0.537 | 0.599 | 0.537 | 0.331 | 0.958 | 0.922 | 0.590 | 0.384 | 0.800 | 0.868 | 1.010 | 0.599 | 0.905 | 1.083 | 1.063 | 0.922 |
|  | 13 | 1 | 0.379 | 0.277 | 0.537 | 0.814 | 0.747 | 0.707 | 1.221 | 1.083 | 0.905 | 0.814 | 0.958 | 0.975 | 0.747 | 0.653 | 0.905 | 1.083 | 1.326 | 1.190 |
|  |  | 2 | 0.379 | 0.223 | 0.642 | 0.653 | 0.642 | 0.653 | 1.168 | 0.922 | 0.800 | 0.868 | 0.853 | 0.868 | 0.853 | 0.760 | 0.958 | 1.137 | 1.379 | 1.190 |
|  |  | 3 | 0.379 | 0.277 | 0.642 | 0.760 | 0.695 | 0.707 | 1.063 | 1.083 | 0.800 | 0.868 | 0.853 | 0.975 | 0.905 | 0.653 | 0.958 | 1.137 | 1.326 | 1.083 |
| 5 | 7 | 1 | 0.221 | 0.116 | 0.484 | 0.277 | 0.432 | 0.438 | 0.274 | 0.223 | 0.274 | 0.223 | 0.326 | 0.331 | 0.484 | 0.384 | 0.537 | 0.331 | 0.747 | 0.545 |
|  |  | 2 | 0.221 | 0.169 | 0.432 | 0.277 | 0.379 | 0.277 | 0.326 | 0.169 | 0.274 | 0.169 | 0.325 | 0.277 | 0.432 | 0.331 | 0.432 | 0.277 | 0.695 | 0.492 |
|  |  | 3 | 0.221 | 0.116 | 0.379 | 0.277 | 0.379 | 0.277 | 0.326 | 0.169 | 0.379 | 0.169 | 0.326 | 0.331 | 0.484 | 0.331 | 0.432 | 0.277 | 0.642 | 0.545 |
|  | 9 | 1 | 0.274 | 0.223 | 0.432 | 0.384 | 0.537 | 0.384 | 0.590 | 0.384 | 0.432 | 0.384 | 0.432 | 0.492 | 0.747 | 0.653 | 0.537 | 0.545 | 0.853 | 0.760 |
|  |  | 2 | 0.326 | 0.169 | 0.484 | 0.438 | 0.484 | 0.384 | 0.642 | 0.384 | 0.432 | 0.331 | 0.484 | 0.438 | 0.642 | 0.599 | 0.590 | 0.438 | 0.747 | 0.814 |
|  |  | 3 | 0.274 | 0.169 | 0.484 | 0.331 | 0.432 | 0.384 | 0.590 | 0.331 | 0.432 | 0.331 | 0.537 | 0.438 | 0.642 | 0.545 | 0.590 | 0.438 | 0.747 | 0.760 |
|  | 11 | 1 | 0.326 | 0.223 | 0.642 | 0.277 | 0.590 | 0.277 | 0.642 | 0.760 | 0.484 | 0.384 | 0.537 | 0.223 | 0.853 | 0.707 | 0.853 | 0.599 | 1.010 | 0.545 |
|  |  | 2 | 0.326 | 0.223 | 0.590 | 0.384 | 0.590 | 0.277 | 0.537 | 0.599 | 0.484 | 0.384 | 0.590 | 0.438 | 0.853 | 0.599 | 0.800 | 0.599 | 0.800 | 0.653 |
|  |  | 3 | 0.379 | 0.169 | 0.484 | 0.438 | 0.537 | 0.331 | 0.590 | 0.599 | 0.484 | 0.384 | 0.537 | 0.277 | 0.747 | 0.653 | 0.800 | 0.438 | 0.800 | 0.653 |
|  | 13 | 1 | 0.379 | 0.277 | 0.590 | 0.599 | 0.747 | 0.599 | 0.905 | 0.760 | 0.642 | 0.438 | 0.484 | 0.814 | 0.747 | 0.814 | 0.905 | 1.083 | 0.958 | 0.975 |
|  |  | 2 | 0.379 | 0.277 | 0.537 | 0.545 | 0.642 | 0.653 | 0.905 | 0.653 | 0.590 | 0.438 | 0.537 | 0.653 | 0.800 | 0.922 | 0.853 | 1.029 | 0.958 | 1.029 |
|  |  | 3 | 0.379 | 0.223 | 0.537 | 0.492 | 0.695 | 0.599 | 0.905 | 0.707 | 0.484 | 0.438 | 0.642 | 0.707 | 0.747 | 0.868 | 0.905 | 0.922 | 1.010 | 0.975 |

(TO BE CONTINUED)

| SUB. | SIZE | R | SHAPE C EXT. | FLEX. | SHAPE D EXT. | FLEX. | SHAPE T EXT. | FLEX. | SHAPE S EXT. | FLEX. | SHAPE W EXT. | FLEX. | SHAPE X EXT. | FLEX. | SHAPE Y EXT. | FLEX. | SHAPE Z EXT. | FLEX. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 1 | 0.221 | 0.116 | 0.379 | 0.277 | 0.379 | 0.169 | 0.379 | 0.223 | 0.326 | 0.169 | 0.221 | 0.277 | 0.379 | 0.331 | 0.432 | 0.384 |
| | | 2 | 0.221 | 0.116 | 0.379 | 0.331 | 0.326 | 0.169 | 0.326 | 0.223 | 0.274 | 0.223 | 0.274 | 0.277 | 0.379 | 0.277 | 0.484 | 0.438 |
| | | 3 | 0.221 | 0.116 | 0.326 | 0.277 | 0.326 | 0.169 | 0.326 | 0.223 | 0.274 | 0.169 | 0.274 | 0.331 | 0.432 | 0.384 | 0.484 | 0.331 |
| | 9 | 1 | 0.274 | 0.223 | 0.537 | 0.599 | 0.432 | 0.331 | 0.537 | 0.545 | 0.379 | 0.331 | 0.484 | 0.384 | 0.537 | 0.492 | 0.537 | 0.438 |
| | | 2 | 0.326 | 0.169 | 0.537 | 0.438 | 0.379 | 0.277 | 0.484 | 0.545 | 0.379 | 0.223 | 0.484 | 0.384 | 0.537 | 0.492 | 0.590 | 0.545 |
| | | 3 | 0.274 | 0.223 | 0.484 | 0.438 | 0.379 | 0.331 | 0.537 | 0.492 | 0.326 | 0.331 | 0.432 | 0.384 | 0.484 | 0.492 | 0.537 | 0.545 |
| | 11 | 1 | 0.326 | 0.223 | 0.642 | 0.599 | 0.432 | 0.545 | 0.590 | 0.814 | 0.379 | 0.331 | 0.432 | 0.653 | 0.000 | 0.760 | 0.747 | 0.760 |
| | | 2 | 0.274 | 0.277 | 0.590 | 0.599 | 0.484 | 0.492 | 0.747 | 0.814 | 0.484 | 0.331 | 0.537 | 0.545 | 0.747 | 0.760 | 0.695 | 0.707 |
| | | 3 | 0.326 | 0.223 | 0.590 | 0.599 | 0.484 | 0.438 | 0.747 | 0.653 | 0.379 | 0.331 | 0.642 | 0.545 | 0.642 | 0.760 | 0.537 | 0.760 |
| | 13 | 1 | 0.379 | 0.599 | 0.642 | 0.760 | 0.379 | 0.653 | 0.537 | 0.707 | 0.484 | 0.462 | 0.800 | 0.599 | 0.432 | 0.384 | 0.905 | 1.029 |
| | | 2 | 0.379 | 0.277 | 0.642 | 0.707 | 0.432 | 0.599 | 0.537 | 0.545 | 0.484 | 0.438 | 0.695 | 0.653 | 0.379 | 0.277 | 0.747 | 1.029 |
| | | 3 | 0.326 | 0.277 | 0.590 | 0.599 | 0.379 | 0.599 | 0.484 | 0.707 | 0.432 | 0.492 | 0.695 | 0.653 | 0.379 | 0.277 | 0.747 | 0.915 |
| 7 | 7 | 1 | 0.221 | 0.116 | 0.274 | 0.277 | 0.326 | 0.277 | 0.379 | 0.223 | 0.274 | 0.169 | 0.379 | 0.277 | 0.432 | 0.331 | 0.432 | 0.384 |
| | | 2 | 0.221 | 0.116 | 0.379 | 0.277 | 0.274 | 0.223 | 0.379 | 0.169 | 0.274 | 0.169 | 0.379 | 0.277 | 0.379 | 0.331 | 0.379 | 0.331 |
| | | 3 | 0.221 | 0.169 | 0.379 | 0.331 | 0.326 | 0.223 | 0.379 | 0.223 | 0.326 | 0.116 | 0.326 | 0.277 | 0.432 | 0.331 | 0.379 | 0.384 |
| | 9 | 1 | 0.274 | 0.116 | 0.326 | 0.438 | 0.326 | 0.331 | 0.695 | 0.599 | 0.326 | 0.331 | 0.379 | 0.438 | 0.432 | 0.438 | 0.537 | 0.653 |
| | | 2 | 0.274 | 0.169 | 0.379 | 0.438 | 0.326 | 0.331 | 0.747 | 0.599 | 0.379 | 0.277 | 0.379 | 0.331 | 0.432 | 0.438 | 0.432 | 0.653 |
| | | 3 | 0.274 | 0.169 | 0.379 | 0.438 | 0.326 | 0.331 | 0.747 | 0.599 | 0.379 | 0.331 | 0.379 | 0.438 | 0.484 | 0.492 | 0.432 | 0.653 |
| | 11 | 1 | 0.326 | 0.169 | 0.379 | 0.545 | 0.326 | 0.331 | 0.537 | 0.707 | 0.379 | 0.438 | 0.484 | 0.492 | 0.484 | 0.760 | 0.432 | 0.814 |
| | | 2 | 0.326 | 0.169 | 0.432 | 0.492 | 0.379 | 0.384 | 0.747 | 0.707 | 0.432 | 0.331 | 0.432 | 0.438 | 0.432 | 0.599 | 0.484 | 0.760 |
| | | 3 | 0.274 | 0.223 | 0.379 | 0.492 | 0.379 | 0.599 | 0.747 | 0.707 | 0.432 | 0.384 | 0.484 | 0.438 | 0.484 | 0.653 | 0.484 | 0.653 |
| | 13 | 1 | 0.326 | 0.223 | 0.326 | 0.492 | 0.695 | 0.438 | 0.800 | 0.760 | 0.800 | 0.707 | 0.484 | 0.653 | 0.484 | 0.653 | 0.484 | 0.707 |
| | | 2 | 0.326 | 0.277 | 0.274 | 0.438 | 0.537 | 0.438 | 0.905 | 1.137 | 0.800 | 0.545 | 0.590 | 0.492 | 0.537 | 0.599 | 0.484 | 0.707 |
| | | 3 | 0.326 | 0.277 | 0.274 | 0.438 | 0.484 | 0.384 | 0.800 | 0.922 | 0.747 | 0.814 | 0.695 | 0.653 | 0.484 | 0.653 | 0.484 | 0.707 |
| 8 | 7 | 1 | 0.221 | 0.116 | 0.379 | 0.277 | 0.379 | 0.277 | 0.379 | 0.331 | 0.326 | 0.223 | 0.484 | 0.384 | 0.379 | 0.277 | 0.550 | 0.492 |
| | | 2 | 0.221 | 0.116 | 0.432 | 0.277 | 0.379 | 0.277 | 0.379 | 0.277 | 0.274 | 0.169 | 0.484 | 0.331 | 0.432 | 0.331 | 0.537 | 0.438 |
| | | 3 | 0.221 | 0.169 | 0.379 | 0.223 | 0.379 | 0.223 | 0.379 | 0.277 | 0.326 | 0.169 | 0.484 | 0.384 | 0.379 | 0.331 | 0.537 | 0.438 |
| | 9 | 1 | 0.274 | 0.169 | 0.432 | 0.492 | 0.379 | 0.331 | 0.537 | 0.492 | 0.484 | 0.331 | 0.484 | 0.438 | 0.537 | 0.545 | 0.642 | 0.868 |
| | | 2 | 0.274 | 0.223 | 0.432 | 0.492 | 0.432 | 0.331 | 0.537 | 0.492 | 0.432 | 0.384 | 0.537 | 0.438 | 0.590 | 0.545 | 0.642 | 0.760 |
| | | 3 | 0.274 | 0.223 | 0.484 | 0.492 | 0.432 | 0.331 | 0.484 | 0.492 | 0.432 | 0.438 | 0.537 | 0.384 | 0.590 | 0.432 | 0.695 | 0.599 |
| | 11 | 1 | 0.379 | 0.277 | 0.695 | 0.653 | 0.484 | 0.438 | 0.958 | 0.868 | 0.537 | 0.599 | 0.747 | 0.653 | 0.853 | 0.814 | 0.800 | 0.922 |
| | | 2 | 0.379 | 0.277 | 0.590 | 0.545 | 0.484 | 0.492 | 0.958 | 0.868 | 0.484 | 0.599 | 0.695 | 0.492 | 0.853 | 0.814 | 0.853 | 0.868 |
| | | 3 | 0.379 | 0.277 | 0.695 | 0.599 | 0.537 | 0.492 | 1.063 | 0.868 | 0.484 | 0.599 | 0.695 | 0.868 | 0.800 | 0.653 | 0.853 | 0.922 |
| | 13 | 1 | 0.432 | 0.331 | 0.695 | 0.707 | 0.853 | 0.707 | 0.958 | 0.975 | 0.642 | 0.599 | 0.695 | 0.814 | 0.853 | 1.029 | 0.905 | 1.137 |
| | | 2 | 0.432 | 0.331 | 0.590 | 0.653 | 0.747 | 0.707 | 0.905 | 1.083 | 0.590 | 0.599 | 0.747 | 0.814 | 0.853 | 0.868 | 0.905 | 1.083 |
| | | 3 | 0.432 | 0.331 | 0.537 | 0.707 | 0.747 | 0.707 | 0.800 | 0.975 | 0.642 | 0.599 | 0.747 | 0.814 | 0.747 | 0.922 | 1.168 | 0.922 |
| 9 | 7 | 1 | 0.169 | 0.221 | 0.384 | 0.432 | 0.438 | 0.432 | 0.384 | 0.484 | 0.331 | 0.326 | 0.545 | 0.537 | 0.599 | 0.590 | 0.653 | 0.747 |
| | | 2 | 0.169 | 0.221 | 0.384 | 0.432 | 0.384 | 0.432 | 0.384 | 0.484 | 0.277 | 0.274 | 0.492 | 0.537 | 0.545 | 0.642 | 0.653 | 0.747 |
| | | 3 | 0.169 | 0.221 | 0.438 | 0.432 | 0.384 | 0.432 | 0.331 | 0.484 | 0.277 | 0.326 | 0.492 | 0.484 | 0.599 | 0.590 | 0.539 | 0.747 |
| | 9 | 1 | 0.223 | 0.274 | 0.707 | 0.642 | 0.599 | 0.590 | 0.653 | 0.853 | 0.599 | 0.537 | 0.599 | 0.747 | 0.868 | 1.010 | 0.653 | 1.010 |
| | | 2 | 0.223 | 0.326 | 0.814 | 0.642 | 0.599 | 0.590 | 0.653 | 0.853 | 0.545 | 0.590 | 0.599 | 0.695 | 0.922 | 0.958 | 0.814 | 1.163 |
| | | 3 | 0.223 | 0.274 | 0.760 | 0.695 | 0.545 | 0.537 | 0.653 | 0.853 | 0.492 | 0.484 | 0.599 | 0.747 | 0.760 | 0.958 | 0.814 | 0.958 |
| | 11 | 1 | 0.223 | 0.274 | 0.653 | 0.853 | 0.707 | 0.695 | 0.922 | 1.168 | 0.707 | 0.747 | 0.653 | 1.063 | 0.653 | 0.958 | 0.975 | 1.326 |
| | | 2 | 0.223 | 0.274 | 0.653 | 0.905 | 0.653 | 0.747 | 0.814 | 1.063 | 0.653 | 0.747 | 0.707 | 1.063 | 0.653 | 0.958 | 0.922 | 1.379 |
| | | 3 | 0.223 | 0.326 | 0.760 | 0.800 | 0.653 | 0.642 | 0.922 | 1.010 | 0.707 | 0.625 | 0.760 | 1.010 | 0.653 | 1.153 | 0.222 | 1.274 |
| | 13 | 1 | 0.331 | 0.379 | 0.760 | 0.853 | 0.707 | 1.010 | 1.244 | 1.484 | 0.653 | 0.695 | 0.707 | 0.905 | 0.707 | 1.326 | 0.868 | 0.853 |
| | | 2 | 0.331 | 0.379 | 0.814 | 0.905 | 0.760 | 0.958 | 1.351 | 1.379 | 0.653 | 0.747 | 0.707 | 0.905 | 0.922 | 0.958 | 1.029 | 1.431 |
| | | 3 | 0.331 | 0.379 | 0.760 | 0.905 | 0.707 | 0.800 | 1.351 | 1.326 | 0.539 | 0.642 | 0.653 | 1.010 | 0.653 | 1.168 | 0.760 | 0.958 |
| 10 | 7 | 1 | 0.169 | 0.116 | 0.274 | 0.223 | 0.379 | 0.277 | 0.274 | 0.169 | 0.274 | 0.169 | 0.379 | 0.223 | 0.379 | 0.331 | 0.537 | 0.277 |
| | | 2 | 0.169 | 0.116 | 0.274 | 0.277 | 0.326 | 0.277 | 0.274 | 0.223 | 0.221 | 0.169 | 0.379 | 0.277 | 0.379 | 0.384 | 0.432 | 0.277 |
| | | 3 | 0.169 | 0.169 | 0.274 | 0.277 | 0.326 | 0.223 | 0.274 | 0.223 | 0.274 | 0.169 | 0.379 | 0.277 | 0.373 | 0.331 | 0.484 | 0.223 |
| | 9 | 1 | 0.221 | 0.169 | 0.432 | 0.331 | 0.379 | 0.331 | 0.484 | 0.384 | 0.326 | 0.277 | 0.432 | 0.277 | 0.432 | 0.384 | 0.484 | 0.438 |
| | | 2 | 0.274 | 0.169 | 0.379 | 0.331 | 0.379 | 0.277 | 0.484 | 0.384 | 0.326 | 0.277 | 0.432 | 0.331 | 0.484 | 0.331 | 0.484 | 0.331 |
| | | 3 | 0.221 | 0.169 | 0.432 | 0.331 | 0.484 | 0.331 | 0.484 | 0.438 | 0.326 | 0.223 | 0.379 | 0.277 | 0.432 | 0.331 | 0.537 | 0.331 |
| | 11 | 1 | 0.326 | 0.223 | 0.326 | 0.384 | 0.432 | 0.384 | 0.537 | 0.599 | 0.484 | 0.384 | 0.484 | 0.223 | 0.432 | 0.492 | 0.642 | 0.492 |
| | | 2 | 0.274 | 0.223 | 0.326 | 0.384 | 0.326 | 0.384 | 0.484 | 0.653 | 0.537 | 0.331 | 0.484 | 0.277 | 0.484 | 0.438 | 0.695 | 0.599 |
| | | 3 | 0.326 | 0.223 | 0.432 | 0.384 | 0.379 | 0.331 | 0.484 | 0.545 | 0.484 | 0.331 | 0.537 | 0.331 | 0.537 | 0.438 | 0.695 | 0.545 |
| | 13 | 1 | 0.326 | 0.223 | 0.379 | 0.331 | 0.484 | 0.331 | 0.695 | 0.707 | 0.432 | 0.384 | 0.537 | 0.492 | 0.537 | 0.438 | 0.590 | 0.599 |
| | | 2 | 0.326 | 0.223 | 0.432 | 0.331 | 0.484 | 0.331 | 0.800 | 0.599 | 0.484 | 0.384 | 0.642 | 0.492 | 0.695 | 0.331 | 0.642 | 0.868 |
| | | 3 | 0.326 | 0.223 | 0.379 | 0.331 | 0.484 | 0.277 | 0.642 | 0.599 | 0.484 | 0.384 | 0.590 | 0.492 | 0.695 | 0.438 | 0.590 | 0.868 |

APPENDIX H

FATIGUE TEST DATA

# ENDURANCE TIME (IN SECONDS) ON STATIC TEST

| GENDER | SUBJECT | Y-11 | O-13 | G-9 | Z-13 | O-11 | Y-13 | T-11 | W-11 | T-13 | T-9 | X-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | 1 | 180 | 165 | 96 | 160 | 85 | 113 | 99 | 98 | 93 | 75 | 52 |
| M | 2 | 307 | 317 | 323 | 235 | 210 | 371 | 413 | 255 | 251 | 271 | 343 |
| M | 3 | 506 | 351 | 966 | 488 | 253 | 425 | 259 | 1262 | 354 | 1069 | 506 |
| M | 4 | 203 | 68 | 77 | 86 | 108 | 70 | 153 | 123 | 73 | 77 | 179 |
| M | 5 | 1186 | 753 | 2045 | 1065 | 1175 | 1258 | 504 | 581 | 1945 | 804 | 1173 |
| M | 6 | 481 | 283 | 291 | 438 | 459 | 422 | 283 | 244 | 176 | 289 | 645 |
| M | 7 | 283 | 237 | 282 | 212 | 198 | 223 | 191 | 271 | 347 | 191 | 234 |
| M | 8 | 280 | 454 | 149 | 185 | 360 | 416 | 221 | 350 | 315 | 446 | 227 |
| M | 9 | 370 | 377 | 267 | 338 | 240 | 286 | 309 | 334 | 290 | 326 | 253 |
| M | 10 | 344 | 436 | 379 | 377 | 620 | 402 | 394 | 148 | 359 | 407 | 503 |
| F | 1 | 157 | 222 | 311 | 552 | 210 | 235 | 348 | 153 | 199 | 134 | 155 |
| F | 2 | 297 | 403 | 384 | 320 | 440 | 358 | 309 | 269 | 301 | 393 | 439 |
| F | 3 | 156 | 164 | 131 | 135 | 181 | 151 | 195 | 176 | 210 | 187 | 187 |
| F | 4 | 355 | 404 | 411 | 324 | 538 | 309 | 310 | 332 | 341 | 247 | 257 |
| F | 5 | 131 | 196 | 146 | 189 | 209 | 185 | 176 | 150 | 198 | 177 | 136 |
| F | 6 | 240 | 327 | 149 | 174 | 208 | 261 | 86 | 240 | 126 | 303 | 186 |
| F | 7 | 63 | 112 | 30 | 95 | 107 | 66 | 89 | 40 | 54 | 153 | 51 |
| F | 8 | 171 | 164 | 36 | 287 | 298 | 140 | 324 | 385 | 236 | 326 | 224 |
| F | 9 | 176 | 115 | 224 | 130 | 241 | 197 | 112 | 189 | 125 | 112 | 218 |
| F | 10 | 232 | 301 | 393 | 260 | 581 | 284 | 208 | 360 | 235 | 436 | 179 |

# ENDURANCE TIME (IN SECONDS) ON IMPULSE TEST

| GENDER | SUBJECT | Y-11 | O-13 | G-9 | Z-13 | O-11 | Y-13 | T-11 | W-11 | T-13 | T-9 | X-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M | 1 | 150 | 139 | 76 | 89 | 67 | 90 | 95 | 77 | 125 | 36 | 37 |
| M | 2 | 110 | 237 | 215 | 169 | 261 | 288 | 240 | 318 | 297 | 323 | 272 |
| M | 3 | 278 | 256 | 134 | 320 | 216 | 211 | 107 | 481 | 322 | 514 | 321 |
| M | 4 | 125 | 94 | 65 | 131 | 63 | 111 | 120 | 123 | 113 | 78 | 153 |
| M | 5 | 479 | 638 | 279 | 578 | 502 | 580 | 655 | 293 | 482 | 480 | 669 |
| M | 6 | 184 | 156 | 190 | 258 | 228 | 229 | 170 | 145 | 97 | 170 | 329 |
| M | 7 | 166 | 130 | 139 | 155 | 124 | 98 | 111 | 174 | 199 | 131 | 157 |
| M | 8 | 276 | 344 | 231 | 168 | 328 | 467 | 244 | 260 | 334 | 410 | 203 |
| M | 9 | 133 | 208 | 65 | 226 | 169 | 172 | 68 | 21 | 189 | 229 | 160 |
| M | 10 | 93 | 333 | 345 | 331 | 280 | 407 | 272 | 87 | 229 | 186 | 253 |
| F | 1 | 150 | 109 | 172 | 215 | 145 | 200 | 167 | 179 | 79 | 109 | 155 |
| F | 2 | 259 | 312 | 96 | 198 | 270 | 414 | 311 | 218 | 154 | 274 | 302 |
| F | 3 | 142 | 155 | 170 | 165 | 188 | 181 | 205 | 275 | 104 | 79 | 212 |
| F | 4 | 309 | 254 | 245 | 223 | 251 | 268 | 188 | 268 | 296 | 296 | 197 |
| F | 5 | 112 | 202 | 77 | 232 | 111 | 153 | 165 | 161 | 138 | 166 | 173 |
| F | 6 | 115 | 258 | 81 | 93 | 96 | 154 | 96 | 52 | 75 | 99 | 62 |
| F | 7 | 52 | 96 | 55 | 99 | 76 | 54 | 129 | 39 | 52 | 103 | 70 |
| F | 8 | 78 | 81 | 121 | 63 | 108 | 34 | 98 | 170 | 34 | 52 | 149 |
| F | 9 | 148 | 87 | 127 | 205 | 304 | 141 | 97 | 169 | 179 | 160 | 215 |
| F | 10 | 242 | 172 | 248 | 234 | 366 | 193 | 123 | 292 | 128 | 367 | 277 |

APPENDIX I

GUARD TEST DATA

| GENDER | SUBJECT | RADIUS | HEIGHT 1 | | | HEIGHT 2 | | | HEIGHT 3 | | | HEIGHT 4 | | | ANTH. MEASUREMENT | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| M | 1 | A | 106.86 | 118.36 | 126.02 | 160.50 | 171.99 | 175.82 | 191.14 | 206.47 | 198.81 | 240.95 | 221.79 | 229.45 | 0.710 | 0.775 | 0.850 |
| | | B | 110.70 | 122.19 | 141.34 | 191.14 | 171.99 | 183.48 | 210.30 | 202.64 | 198.81 | 217.96 | 221.79 | 240.95 | | | |
| | | C | 103.03 | 103.03 | 103.03 | 149.00 | 145.17 | 171.99 | 194.98 | 187.31 | 198.81 | 237.12 | 244.78 | 210.30 | | | |
| M | 2 | A | 72.39 | 95.37 | 41.74 | 126.02 | 114.53 | 126.02 | 149.00 | 149.00 | 149.00 | 129.85 | 129.85 | 129.85 | 0.600 | 0.700 | 0.800 |
| | | B | 60.89 | 45.57 | 53.23 | 114.53 | 103.03 | 106.86 | 126.02 | 122.19 | 126.02 | 179.65 | 149.00 | 149.00 | | | |
| | | C | 64.72 | 80.05 | 41.74 | 114.53 | 126.02 | 118.36 | 141.34 | 129.85 | 133.68 | 141.34 | 156.67 | 145.17 | | | |
| M | 3 | A | 95.37 | 122.19 | 129.85 | 152.84 | 145.17 | 160.50 | 149.00 | 145.17 | 149.00 | 160.50 | 164.33 | 164.33 | 0.675 | 0.740 | 0.850 |
| | | B | 106.86 | 122.19 | 106.86 | 137.51 | 129.85 | 145.17 | 171.99 | 164.33 | 164.33 | 145.17 | 156.67 | 152.84 | | | |
| | | C | 122.19 | 114.53 | 106.86 | 145.17 | 145.17 | 141.34 | 160.16 | 160.16 | 164.33 | 179.65 | 179.65 | 171.99 | | | |
| M | 4 | A | 83.88 | 103.03 | 99.20 | 114.53 | 137.51 | 114.53 | 126.02 | 126.02 | 126.02 | 137.51 | 152.84 | 137.51 | 0.650 | 0.750 | 0.825 |
| | | B | 91.54 | 83.88 | 87.71 | 114.53 | 118.36 | 122.19 | 133.68 | 122.19 | 137.51 | 137.51 | 145.17 | 149.00 | | | |
| | | C | 103.03 | 87.71 | 87.71 | 129.85 | 133.68 | 137.51 | 129.85 | 110.70 | 110.70 | 133.68 | 126.02 | 126.02 | | | |
| M | 5 | A | 103.03 | 103.03 | 110.70 | 164.33 | 175.82 | 179.65 | 225.62 | 202.64 | 210.30 | 187.31 | 198.81 | 202.64 | 0.680 | 0.760 | 0.820 |
| | | B | 103.03 | 83.88 | 145.17 | 160.50 | 152.84 | 156.67 | 168.16 | 168.16 | 160.50 | 191.14 | 217.96 | 214.13 | | | |
| | | C | 103.03 | 91.54 | 99.20 | 168.16 | 168.16 | 149.00 | 179.65 | 187.31 | 183.48 | 244.78 | 248.61 | 252.44 | | | |
| M | 6 | A | 76.22 | 80.05 | 80.05 | 118.36 | 141.34 | 133.68 | 137.51 | 145.17 | 137.51 | 155.67 | 145.17 | 149.00 | 0.620 | 0.730 | 0.800 |
| | | B | 60.89 | 68.56 | 68.56 | 129.85 | 137.51 | 145.17 | 137.51 | 145.17 | 149.00 | 141.34 | 145.17 | 145.17 | | | |
| | | C | 57.06 | 60.89 | 80.05 | 145.17 | 141.34 | 129.85 | 137.51 | 145.17 | 149.00 | 155.67 | 145.17 | 145.17 | | | |
| M | 7 | A | 103.03 | 114.53 | 122.19 | 145.17 | 145.17 | 152.84 | 240.95 | 206.47 | 229.45 | 210.30 | 194.98 | 210.30 | 0.640 | 0.760 | 0.820 |
| | | B | 87.71 | 103.03 | 114.53 | 141.34 | 141.34 | 160.50 | 194.98 | 191.14 | 202.64 | 191.14 | 199.94 | 194.98 | | | |
| | | C | 76.22 | 91.54 | 106.86 | 145.17 | 129.85 | 137.51 | 179.65 | 187.31 | 160.50 | 171.99 | 179.65 | 175.82 | | | |
| M | 8 | A | 95.37 | 95.37 | 87.71 | 129.85 | 129.85 | 129.85 | 137.51 | 126.02 | 137.51 | 129.85 | 152.84 | 160.50 | 0.690 | 0.800 | 0.860 |
| | | B | 103.03 | 95.37 | 99.20 | 122.19 | 118.36 | 126.02 | 137.51 | 129.85 | 137.51 | 133.68 | 122.19 | 129.85 | | | |
| | | C | 99.20 | 87.71 | 91.54 | 129.85 | 118.36 | 118.36 | 126.02 | 126.02 | 133.68 | 129.85 | 126.02 | 126.02 | | | |
| M | 9 | A | 156.67 | 149.00 | 133.68 | 194.98 | 210.30 | 194.98 | 260.10 | 267.76 | 271.59 | 233.20 | 244.78 | 240.61 | 0.730 | 0.795 | 0.850 |
| | | B | 114.53 | 133.68 | 129.85 | 194.98 | 187.31 | 194.98 | 183.48 | 194.98 | 191.14 | 225.62 | 225.62 | 237.12 | | | |
| | | C | 126.02 | 141.34 | 114.53 | 191.14 | 175.82 | 179.65 | 240.95 | 240.95 | 240.95 | 214.13 | 175.82 | 187.31 | | | |
| F | 1 | A | 91.54 | 95.37 | 91.54 | 122.19 | 99.20 | 95.37 | 122.19 | 110.70 | 126.02 | 133.68 | 145.17 | 122.19 | 0.575 | 0.675 | 0.750 |
| | | B | 99.20 | 87.71 | 91.54 | 110.70 | 106.86 | 87.71 | 126.02 | 122.19 | 114.53 | 118.36 | 110.70 | 122.19 | | | |
| | | C | 114.53 | 95.37 | 106.86 | 114.53 | 103.03 | 118.36 | 122.19 | 106.86 | 114.53 | 125.02 | 122.19 | 114.53 | | | |
| F | 2 | A | 45.57 | 53.23 | 60.89 | 60.89 | 49.40 | 64.72 | 53.23 | 53.23 | 64.72 | 53.23 | 53.23 | 57.06 | 0.580 | 0.680 | 0.710 |
| | | B | 53.23 | 60.89 | 53.23 | 41.74 | 41.74 | 68.56 | 57.06 | 41.74 | 37.91 | 49.40 | 57.06 | 53.23 | | | |
| | | C | 45.57 | 49.40 | 41.74 | 57.06 | 57.06 | 64.72 | 49.40 | 41.74 | 45.57 | 57.06 | 53.23 | 53.23 | | | |
| F | 3 | A | 53.23 | 26.42 | 41.74 | 49.40 | 53.23 | 53.23 | 53.23 | 53.23 | 53.23 | 57.06 | 41.74 | 41.74 | 0.580 | 0.720 | 0.720 |
| | | B | 26.42 | 34.08 | 30.25 | 53.23 | 41.74 | 41.74 | 53.23 | 49.40 | 49.40 | 57.06 | 49.40 | 41.74 | | | |
| | | C | 18.75 | 22.58 | 37.91 | 49.40 | 45.57 | 49.40 | 49.40 | 53.23 | 49.40 | 49.40 | 45.57 | 45.57 | | | |
| F | 4 | A | 41.74 | 45.57 | 41.74 | 72.39 | 68.56 | 72.39 | 76.22 | 83.88 | 80.05 | 76.22 | 57.06 | 64.72 | 0.530 | 0.630 | 0.700 |
| | | B | 83.88 | 76.22 | 83.88 | 83.88 | 87.71 | 80.05 | 72.39 | 72.39 | 68.56 | 76.22 | 53.23 | 60.89 | | | |
| | | C | 53.23 | 49.40 | 53.23 | 64.72 | 57.06 | 57.06 | 95.37 | 87.71 | 99.20 | 57.06 | 53.23 | 53.23 | | | |
| F | 5 | A | 53.23 | 49.40 | 49.40 | 64.72 | 53.23 | 53.23 | 68.56 | 72.39 | 53.23 | 83.88 | 68.56 | 64.72 | 0.580 | 0.620 | 0.700 |
| | | B | 57.06 | 60.89 | 64.72 | 80.05 | 68.56 | 64.72 | 68.56 | 76.22 | 53.23 | 72.39 | 53.23 | 64.72 | | | |
| | | C | 72.39 | 57.06 | 41.74 | 68.56 | 53.23 | 60.89 | 76.22 | 72.39 | 72.39 | 80.05 | 64.72 | 68.56 | | | |
| F | 6 | A | 64.72 | 68.56 | 64.72 | 60.89 | 76.22 | 76.22 | 68.56 | 53.23 | 53.23 | 99.20 | 103.03 | 95.37 | 0.580 | 0.650 | 0.700 |
| | | B | 53.23 | 72.39 | 68.56 | 72.39 | 72.39 | 53.23 | 95.37 | 95.37 | 95.37 | 72.39 | 68.56 | 60.89 | | | |
| | | C | 49.40 | 57.06 | 60.89 | 72.39 | 53.23 | 57.06 | 64.72 | 95.37 | 99.20 | 83.88 | 95.37 | 87.71 | | | |
| F | 7 | A | 133.68 | 68.? | 114.53 | 129.85 | 137.51 | 149.00 | 118.36 | 129.85 | 122.19 | 125.02 | 118.36 | 141.34 | 0.650 | 0.720 | 0.780 |
| | | B | 106.86 | 103.03 | 129.85 | 103.03 | 126.02 | 129.85 | 137.51 | 122.19 | 126.02 | 122.19 | 145.17 | 149.00 | | | |
| | | C | 122.19 | 122.19 | 110.70 | 122.19 | 99.85 | 133.68 | 129.85 | 103.03 | 129.85 | 164.33 | 164.33 | 160.50 | | | |
| F | 8 | A | 60.56 | 64.72 | 53.23 | 87.71 | 91.54 | 91.54 | 95.37 | 103.03 | 106.86 | 95.37 | 95.37 | 103.03 | 0.533 | 0.620 | 0.675 |
| | | B | 45.57 | 57.06 | 53.23 | 99.20 | 99.20 | 91.54 | 87.71 | 91.54 | 83.88 | 110.70 | 106.86 | 87.71 | | | |
| | | C | 53.23 | 45.57 | 49.40 | 87.71 | 83.88 | 87.71 | 103.03 | 114.53 | 99.20 | 95.37 | 83.88 | 106.86 | | | |
| F | 9 | A | 26.42 | 37.91 | 37.91 | 83.88 | 76.22 | 80.05 | 87.71 | 95.37 | 83.88 | 91.54 | 68.56 | 87.71 | 0.670 | 0.720 | 0.800 |
| | | B | 45.57 | 53.23 | 53.23 | 76.22 | 87.71 | 80.05 | 87.71 | 87.71 | 87.71 | 99.20 | 91.54 | 99.20 | | | |
| | | C | 53.23 | 49.40 | 45.57 | 57.06 | 68.56 | 83.88 | 83.88 | 76.22 | 87.71 | 83.88 | 87.71 | 83.88 | | | |