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Ergonomic Assessment of Countertop Height for the Design of a New Temperature Chamber

Final Report

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Ergonomic Assessment of Countertop Height for the Design of a New Temperature Chamber

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Abstract

Units Under Tests (UUTs) will be serviced from a "countertop" that's located on the uppermost side of a new temperature chamber. An ergonomic assessment was performed to determine a working height that ensures the technicians will be able to reach the components inside the UUT in a safe and reliable manner. A review of the anthropometric data relative to elbow height was used to make this determination. Nominal work height was 41.89 inches for the population of interest, ranging from 5th to 95th percentile. After adjusting for the height and centerline dimensions of the UUT, the "countertop" was defined to be ~ 26.0 inches. Next, a range of working heights was defined to accommodate the tasks involved with servicing the UUTs: from 38.0 to 45.8 inches. These values were compared with design guidelines from the general literature. The results were found to converge relatively well with the external references.

ACKNOWLEDGMENTS

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1. PROBLEM STATEMENT

Department 02256, Air Delivered Weapons Tester Development, is designing a custom temperature chamber. This equipment is illustrated in Figure 1. The chamber is approximately 4 feet wide and 14–15 feet long. As shown in Figure 1, a "countertop" is featured on top of the chamber. The "countertop" is a platform for servicing Units Under Test (UUTs). UUTs are typically 30 inches deep and 32 inches in height. The width of a UUT is assumed to vary, but can't exceed 4 feet, the total width of the countertop.

Technicians will service the UUTs from a natural standing position. Tasks include reaching inside to make up cable connections and perform other assorted maintenance activities. Given the nature of the tasks the technicians will be doing, they must have unhindered access to all the parts housed within the UUT. For instance, the workplace should be arranged in a way that lets the technicians reach into the UUT and perform the work smoothly and efficiently. Further, it's impractical to simply reach the parts unless they can be seen as well. Additionally, the technicians should be able to perform these duties without having to stoop or force themselves into an awkward position to reach a cable connection. Finally, it's important to note that workplace accessibility must accommodate the entire workforce, regardless of their size or stature.

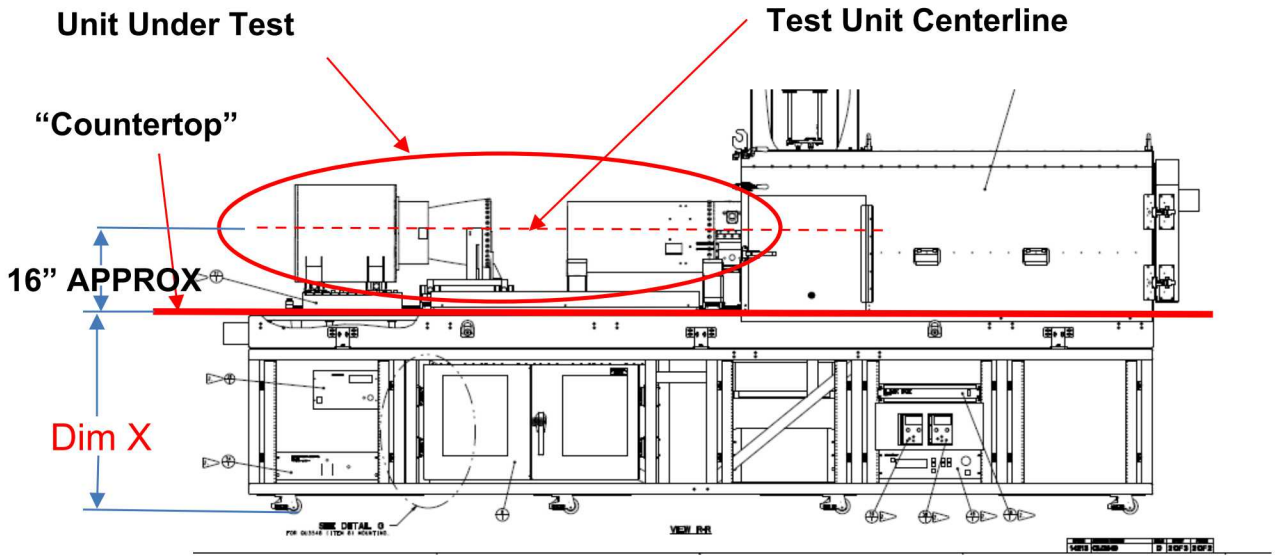

Figure 1. Temperature Chamber – Representative Side View

A workplace that's optimally accessible and fitting to the task won't be achievable if the work height is too high, or conversely, too low. Therefore, it's important to know what the working height should be, particularly in terms of how the technicians interact with the UUT. Essentially, working height is the height above the floor at which the user actually engages the task. For instance, Das and Sengupta (1996) determined that working height for a supermarket checkout station is equivalent to the average height of the grocery item that's placed on the conveyor belt.

Once the working height is known, it's possible to define the "countertop" height above the floor. Accordingly, while working height is relative to the task, the "countertop" provides a platform for conducting the work. Referring again to the research reported by Das and Sengupta

(1996), the conveyor belt for the supermarket checkout station would be analogous to "countertop" height; i.e., the surface that grocery items are placed upon. Therefore, to avoid the problem of having a workplace that's either too high or too low for the intended workforce, an ergonomic assessment was performed to: (1) Identify a working height that permits optimal accessibility to all relevant components and cable connections that are housed within the UUT; and (2) Define a height for the "countertop" that's commensurate with the requirements for working height. The technical approach and findings that resulted in a specification for these dimensions is presented in the next sections.

2. METHOD AND ANALYSIS

The design and layout of the Temperature Chamber in Figure 1 was reviewed to understand what the working height should be relative to the UUT. The results of the review revealed that optimal accessibility will be assured if the work height was coincident with the UUT centerline (16 inches above the base). The rationale being that the technician's job requires unhindered access to all the components within the UUT, regardless of where they might be located. Because of the variability in terms of how the components will be packaged, it was reasonable to fix the work height at the centerline.

Standing elbow height, the vertical distance between the floor and elbow, is generally considered to be the best indicator of work height (Cohen, Gjessing, & Fine, 1997; MacLeod, 2000). For example, the optimal heights for kitchen countertops are usually based on proximity to elbow height (Salant, 2009). Other research suggests that pipetting activities are less stressful when the work surface is at the same height as the tip of the pipette and the hand at elbow height (Jung-Keun & Buchholz, 2013). (Cohen, Gjessing, & Fine, 1997) also reported that musculoskeletal injuries are less prevalent when working height aligns with elbow height.

Therefore, it's apparent that standing elbow height must first be identified before one can infer what the working height should be. Once working height is known, it's possible to determine the height of the "countertop." Standing elbow height, the UUT, and the "countertop" for the Temperature Chamber are described in Figure 2. In Figure 2, The UUT is positioned on top of the "countertop." Whereby, the "countertop" is simply the area encompassing the upper side of the Temperature Chamber. Also, Figure 2 illustrates how working height is defined by the standing elbow height relative to the centerline of the UTT.

To establish working height, anthropometric data was examined for standing elbow height, from the largest to the smallest members of the expected workforce. Because human dimensions are highly variable, standing elbow height was collected across three percentile ranges (5^{th}, 50^{th}, and 95^{th} percentiles). Those among the 95^{th} percentile have elbow heights at the higher range. Conversely, those among the 5^{th} percentile have elbow heights at the lower range. Whereas, the 50^{th} percentile resides in the middle range. Since the workforce includes both male and female populations, data was collected that's specific to each gender.

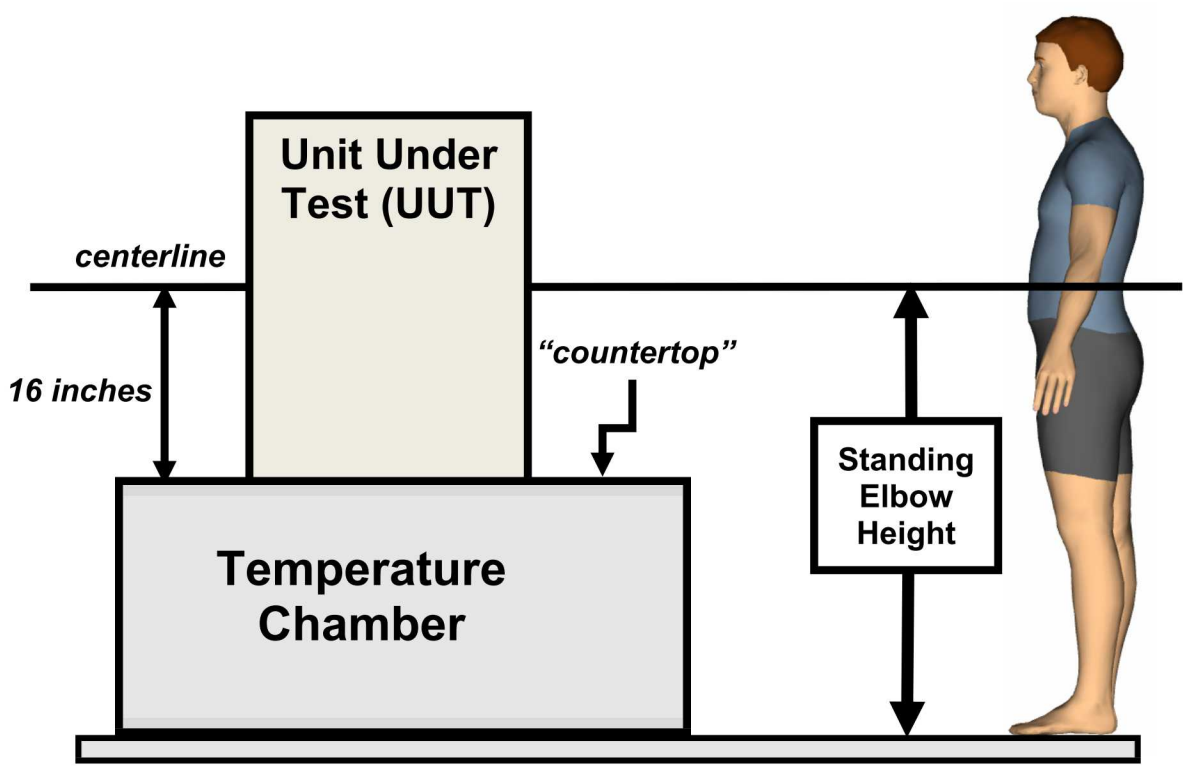

Figure 2. Standing Elbow Height, Centerline of the UUT, and the "Countertop." Working height is defined by elbow standing height relative to the Centerline of the UUT. (Image of the manikin was adapted from Penn State Open Design Lab, http://openlab.psu.edu/tools/fetcher.php , 2014).

Lastly, to attain sufficient variability across populations, anthropometric data was examined from a variety of different sources. These sources are listed in Appendix A, *Sources of Anthropometric Data*. This list includes measurements of elbow heights from civilian sources and military personnel from a wide range of occupational specialties. The 5th, 50th, and 95th percentile ranges that were derived from these different sources are presented in Tables 1 and 2 for female and male populations respectively. As shown in Table 1, elbow height for 5th percentile females ranged from 36.54–39.09 inches. 50th percentile ranged from 39.29–40.39 inches. While, 95th percentile females ranged from 42.09–43.58 inches. For the male population shown in Table 2, elbow height for the 5th percentile male population ranged from 39.21–41.26 inches. The 50th percentile male population ranged from 42.32–44.17 inches. Finally, the 95th percentile male population data ranged from 45.91–47.24 inches.

These percentiles are plotted in Figure 2.1. Red is used to code all values drawn from the female population and black represents the values drawn from the male population. In general, workplace design guides suggest that the human-system interface should broadly accommodate all possible members of the workforce, from 5th percentile females to 95th percentile males (O'Hara, Brown, & Lewis, 2002).

As seen in Figure 2.1, 36.54 inches was the lowest value reported for 5th percentile females and the highest value reported for 95th percentile males was 47.24 inches. (In Figure 2.1, the upper and lower bounds are highlighted to emphasis their position relative to the complete spectrum of data.)

Table 1: Anthropometric Data – Elbow Height – Female Population

Source Code (FEMALE) *	5th Percentile (Inches)	50th Percentile (Inches)	95th Percentile (Inches)
A5	39.09	40.16	43.27
A6	39.05	40.31	43.58
B	38.27	39.57	42.72
C	Not-Available	40.39	Not-Available
D	36.54	39.29	42.09
E	36.69	39.45	42.68
MIN (Inches)	36.54	39.29	42.09
MAX (Inches)	39.09	40.39	43.58
MIN (Feet)	3.05	3.27	3.51
MAX (Feet)	3.26	3.37	3.63

* See Appendix A for source descriptions

Table 2: Anthropometric Data – Elbow Height –Male Population

Source Code * (MALE)	5th Percentile (Inches)	50th Percentile (Inches)	95th Percentile (Inches)
A1	40.24	43.39	46.61
A2	41.26	44.17	47.24
A3	40.00	43.11	46.38
A4	40.59	43.50	46.42
B	39.57	42.91	46.46
C	Not-Available	43.50	Not-Available
D	39.21	42.32	45.91
E	39.53	42.64	45.94
MIN (Inches)	39.21	42.32	45.91
MAX (Inches)	41.26	44.17	47.24
MIN (Feet)	3.27	3.53	3.83
MAX (Feet)	3.44	3.68	3.94

* See Appendix A for source descriptions

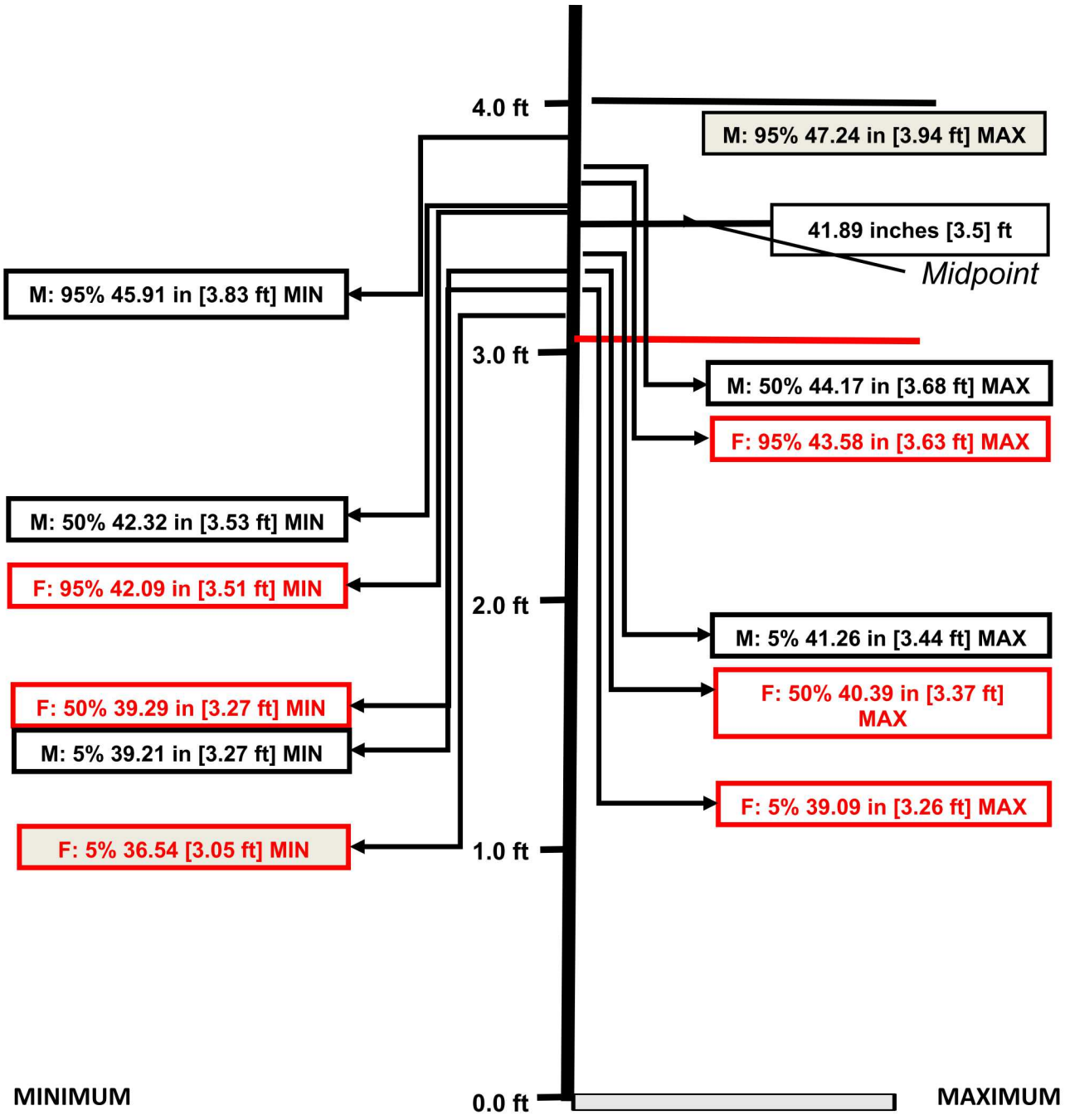

Figure 2.1: Graphical Illustration of Percentile Rankings for Standing Elbow Height (Males and Females). Midpoint is set between the smallest 5th percentile female and the largest 95th percentile male.

In Figure 2.1, the midpoint is shown at 41.89 inches between 47.24 inches [95th percentile male] and 36.54 inches [5th percentile female]. As the midpoint is centrally located in a region between the upper and lower ends of the spectrum, it was selected as the nominal working height for the broadest number of people.

After working height was identified, it was possible to calculate a height for the "countertop." In revisiting the dimensions for the UUT, it's 32 inches high with a centerline at 16 inches, and nominal working height is based on the elbow standing height relative to the centerline of the UUT (41.89 inches). As a result, "countertop" height was determined by subtracting the working height (standing elbow height) (41.89 inches) from the centerline of the UUT (16 inches). Thus, the height of the "countertop" was determined to be 25.89 inches, ~ 26.0 inches.

Once the height of the countertop was identified, the nominal working height was slightly adjusted to accommodate the range of tasks expected to be performed. For tasks involving the UUT, it's assumed that a certain amount of precision, and perhaps delicacy will be required to accomplish the work. To accommodate these activities, it's acceptable to set the working height between 50 (2.0 inches) and 100 mm (3.9 inches) below elbow height; and between 50 (2.0 inches) and 100 mm (3.9 inches) above elbow height (Adler, 2002). Though little guidance was available to determine the range that's fitting to the current study, Das and Grady (1983) reported, "working height can vary several centimetres up or down without any significant effect on performance" (p. 434). Unfortunately, it's not obvious what the authors meant by "several centimetres." Although it's inferred from the passage that working height can be described more broadly, within a more permissible range of acceptance. Therefore, given Adler's upper and lower boundary of 100 mm, it was reasonable to conclude that work height falls within a range of values: from 45.8 inches at the upper boundary (41.89 inches + 3.9 inches); to 38.0 inches at the lower boundary (41.89 – 3.9 inches).

By establishing the working height within this range, it appears that technicians having a variety of different elbow heights can reach into the UUT and access the components housed within it. Also, for this given range, it's predicted that tasks can be achieved while positioning oneself in a natural upright posture. Finally, for the range specified, it's not likely that the technicians, regardless of their individual elbow height, would have to stretch and strain to reach a component. These relationships, with respect to the UUT centerline, working heights (Standing Elbow Height), and countertop height, are presented in Figure 2.2.

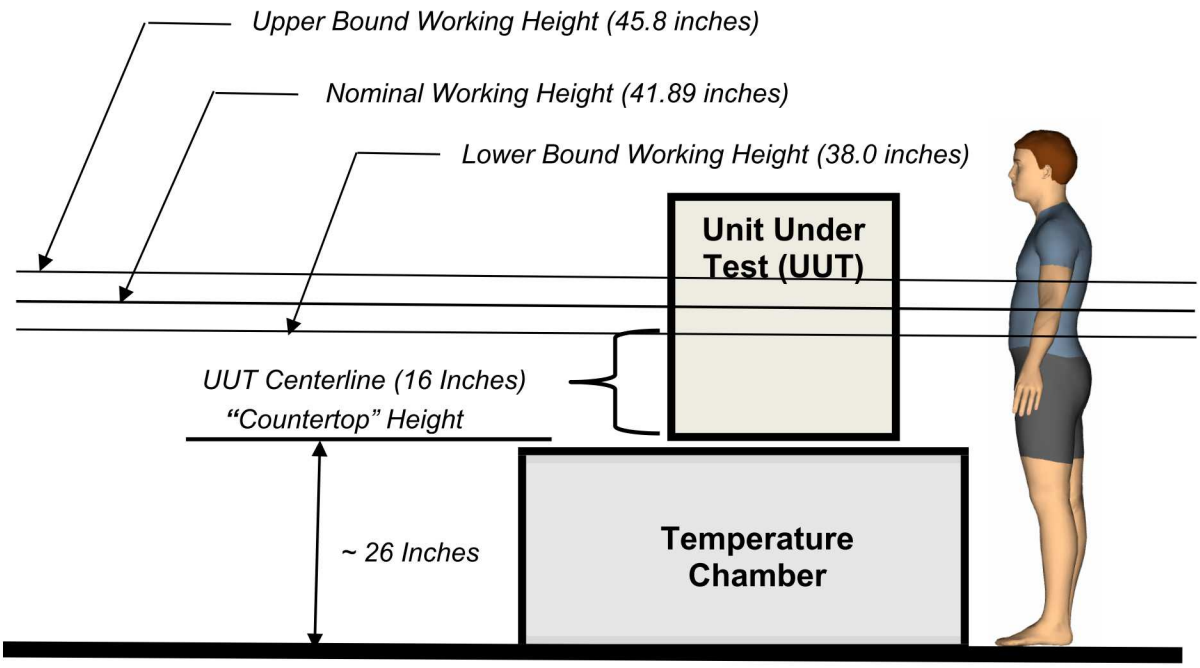

Figure 2.2. "Countertop" Height Relative to Working Height (Standing Elbow Height), and UUT Centerline. (Image of the manikin was adapted from Penn State Open Design Lab, http://openlab.psu.edu/tools/fetcher.php, 2014).

3. DATA COMPARISON

Design guidelines were reviewed to identify height recommendations for stand up work stations in an industrial setting. Specifically, recommended work heights were sought to determine if they're found to be comparable with a nominal working height of 41.89 inches (Range: 45.8 – 38.0 inches) Relevant values are listed in Table 3.

Table 3: Ergonomic Guidelines for Stand Up Workstations

Type of Workplace	Height Above Floor Level *	Reference
Service Counter Height	40 – 41 Inches	(Tillman, et al., 2016)
Work Bench Height	36 Inches	(Tillman, et al., 2016)
Drafting Table	38 Inches	(Tillman, et al., 2016)
Standing Work Surface Height	40 Inches	(Eastman Kodak, 1983)

*** For comparative purposes, Height Above Floor Level is analogous to a dimension for work height.**

On inspection of the dimensions shown above, it can be seen that the range of working height are in general agreement with the dimensions drawn from the guidelines, ranging from 36 inches to 41 inches. Thus, it's reasonable to assume that the working height that was developed to service the UUTs is consistent with the guidelines reported in (Tillman, 2016) and (Kodak, 1983).

4. CONCLUDING REMARKS

In addition to the recommendation that was derived from the study, other aspects of the association between human dimensions and countertop should also be taken into consideration. For this reason, some thought should be given to how far back inside the UUT that the components are likely to be located. For instance, if it can be assumed that the majority of reaches into the UUT will be accomplished by bending the elbow, the distance between Elbow Height (Standing) to Fist for the 95th percentile human is 16.2 inches. Conversely, the distance for the 5th percentile human is 12.6 inches (Kodack, 1983; 1986).[1] Thus, components should be located towards the front of the UUT; i.e., where they can be reached by the smallest individual.

Lastly, for all standing workplaces, the technicians will need a place to put their feet, particularly if they're positioned at the edge of the work surface. To accommodate "kick space," provide a 4 inches (horizontal) x by 4 inches (vertical) clearance at floor level (O'Hara B. L., 2002).

[1] In this example, anthropometric data was collected from a 50/50 mix of males and females (Kodack, 1983; 1986).

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APPENDIX A: SOURCES OF ANTHROPOMETRIC DATA

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