This paper focuses on the aspects of fit in functional apparel. Fit typically refers to the appearance and comfort of a garment but this alone is insufficient for functional garments. Hence, a third requirement ‘functional ease’ has been introduced which refers to the need of the functional garment to be able to adapt to the movement of the individual while maintaining its purpose. Functional apparel can be as simple as the use of a special fabric in athletic gear to a complicated enclosed environment which must incorporate a life support system. Lab and field analysis of movement is recommended during the design process and once the prototypes are developed. Visual cues to proper fit are discussed. The options of adding flexibility and elasticity to the functional garment are given with suggestions on how to obtain variability in fit and enhance function of the garment. The fit of functional garments is considered successful when the needs of the wearer are balanced with the required functionality of the garment.

1 Introduction
The fit of clothing is an issue that has often concerned researchers, retailers, apparel manufacturers and consumers but its importance becomes paramount when working with functional clothing. Fit typically has two aspects – comfort and appearance. Comfort is decided by the individual wearing the garment and appearance refers to the look, style and fashion of the garment1, 2. Fit must take into account the shape of the wearer, texture, drape and weight of the fabric, and how the garment is worn. Fit is typically determined with the person standing still and upright. In the case of functional garments, what is worn in conjunction with the garment and the ability to accommodate the movement of the body is also important.

Judging fit in fashion apparel involves five basic factors, namely the grain of the fabric, the construction lines, the set of the garment, the balance and the ease2. Grain refers to the lengthwise and crosswise yarns woven together to create fabric. The lengthwise grain should fall perpendicular to the floor and the crosswise grain should be parallel to the floor. The construction lines should lie on the body in the proper position; the shoulder seams sit on the shoulder, the side seams run down the side of the body and remain perpendicular with the floor. Horizontal seamliness, such as a waistline are parallel to the floor. Set of the garment refers to the idea that a well fitted garment should have no wrinkles when the person is standing still. Balance is achieved when the garment is symmetrical and hangs away from the body identically on the right and left sides of the body (assuming the design allows for symmetry). Ease refers to the difference between the body measurement of the person and the corresponding measurement of the garment. Ease, which affects movement, will be discussed in more detail later. These five basic factors are, however, the generalized rules to follow and may not apply to all garments, certainly not to all functional garments.

Fitting a fashion garment can be difficult not only due to the balancing of the five factors but due to the fact that people are all different shapes and sizes. Very few people have exactly the same measurements that a manufacturer uses to determine the size of a garment. Manufacturers develop their own size charts based on their experience and customer feedback. Designers may interpret the fit of a garment for various styles differently than the consumer.

Fit, while difficult to achieve in fashion apparel, takes on a new dimension when discussing functional garments. While a person likes to look good and good fit is a variable of this, looks often become secondary in functional apparel. Functional clothing must fit the body so that the person can move, sit and perform work duties or athletic activities. Functional garments serve a purpose, such as protecting the person wearing the item and this purpose is paramount. However, this purpose may be compromised due to poor fit.

Keywords: Anthropometrics, Field testing, Functional apparel, Functional ease, Motion analysis
2 Functional Ease

Traditionally, there are two types of ease required when fitting garments; the first is the wearing ease, or the amount of ease needed in order to allow the person to move and perform everyday tasks. The second kind of ease is the design or style ease. This type of ease is chosen by the designer to create the silhouette desired. For functional garments, a third kind of ease needs to be determined — functional ease, which is given to allow movement.

The amount of ease differs for the type of garment and end use. A garment worn next to the body would have less ease than one intended to be worn over clothing. When layering garments, you not only have to take into consideration the extra bulk the under layer adds but the friction which may be caused by fabric surfaces. Standard ease guidelines give minimum or average requirements for wearing ease. For example, ease around the chest should be 3 inches, the waist should have ½ inch and the hips should have 2 inches. Garments which go over other garments, such as a suit jacket, would have additional ease to accommodate the extra layer of clothing and so ease for this garment may be 3-6 inch around the chest depending on the style. Knit fabrics require less ease than wovens and how much ease is required can be determined by the amount of stretch inherent in the fabric. The ease for woven fabrics will vary depending on the weight of the fabric; heavier fabrics require more ease.

Typically, fit refers to clothing that hangs smoothly from the shoulders and does not sag, bind, pull, twist or cling to the body while standing still. Clothing must also adjust to movements without strain. Good fit allows the wearers not to think about their clothing but go about their day with confidence. Standard ease guidelines cannot always be used to guide the designer of functional clothing. The five factors of fit are not always achievable when working with functional garments as it is not always possible for the shoulder of the garment to lie on the shoulder of the person; perhaps they are wearing a self-contained breathing apparatus and the functional garment is resting on that unit. It is not always necessary or desirable for the seams to be perpendicular to the floor or that every wrinkle is taken out.

Ease will also need to be added to the functional garment depending on the movement required for the workers to complete their tasks. Street clothing is considered good fitting if the garment looks good when the person is standing still and erect, yet can still perform functions such as typing on a keyboard, sitting and driving a car. Functional clothing must allow for full coverage in all positions, even extreme positions, and this will alter what would be considered a good fit. The design of the garment may take movement into account – bellows or pleats on the back to allow for arm movement, or a crotch gusset to allow for leg extension for example. Good fit for functional clothing is considered when the garment allows the body to function and neither restrict the wearer’s movements nor interfere with their required tasks.

3 Movement Analysis

Mobility and motion are closely related to fit in functional garments. Individuals must be able to move in their protective garments without straining themselves or being restricted. Firefighters must be able to move quickly if a building is about to fall and athletes require range of motion in order to play a sport. Minimally, the individuals must be able to perform their job or activity without worry of a reduction or restriction of movement.

Mobility in functional garments is often restricted due to bulky layers or rigid protection. There may also be a trade-off required – less padding for more mobility. The more layers of padding added, the less likely the individual will be able to perform certain functions. The designer of functional garments may need to create a solution for these issues in order to provide the level of protection required as well as the level of movement.

An analysis of the movements while performing on-the-job tasks must be ascertained. This can be accomplished in numerous ways – observation, photographic analysis, questionnaires, surveys and interviews are some suggestions. A combination of these methods is often advised in order to account for a variety of methods and differentiation between subgroups. For example, firefighters in one part of the United States prefer to enter fire engulfed buildings in a squat position, while other fire departments prefer to enter while standing. This method is referred to as a multi-method field analysis and can help in the design or redesign of a garment.

Analysis of movement can take place in a laboratory and the action can be filmed or photographed for later analysis. While the conditions would be contrived, the action required would be well
documented. Individuals should be wearing minimal clothing in order to record the full range of movement required without hindrances. It is often suggested to have the participant wearing or holding the accessories needed in order to perform their required duties. For example, if you are looking at ice hockey players, having them hold their hockey sticks while performing the action would give a more realistic image of their posture and movements. It could also help the individual in recreating the actual movements in the unnatural or unfamiliar laboratory setting.

Full motion analysis, which will not be covered completely here, would entail understanding how the angles of the body change while in motion and by what amount. The individuals may be required to reach above their head or bend to the ground on their knees. These extreme movements would require additional fabric in the places of expansion, in the case of bending to the ground this area would be over the buttocks and knees.

While much can be ascertained in a lab setting, a field visit is recommended so that the designer may view the participants in their own environment. While the individuals are wearing the functional garment, the viewer takes notes as to the positioning of the body. In particular, extreme positions must be identified and later referred to when adding ease to a garment to avoid restricting the wearer. Photographs can also be taken and analyzed later. Issues to identify include the direction of wrinkles in order to identify areas of strain, excess or sagging fabric, and common working positions. Also note what items are worn with the garment such as a hat, glasses, boots or shoes, street clothing, gloves, and helmets as the final garment must be able to work with all supplemental items.

When a body moves against fabric, it can take extra energy to push against the fabric. If this is an issue, the design of the functional garment should incorporate a working position in that area. This is when a permanent bend is put into the design of the garment, by the use of patterning, the addition of pleats or the lengthening of fabric is advised to relieve some of the pressure. Bicycle shorts are made with a bend at the hip and with a higher rise on the back in order to accommodate the position of the rider. In this way the rider is expending energy only in pedaling the bike and not in keeping their legs bent at the hip.

4 Visual Analysis and Prototype Testing

Visual analysis of the garment is essential to obtain good fit. Garments are not made for mannequins and therefore fit must be determined for the body as it moves and changes positions. This is particularly important in the development and fit of functional garments. If the workers cannot perform their duties without being hampered by their garment, then the garment must be determined not to fit. A live model can also verbalize any discomfort, pulling or other issues pertaining to fit. It is recommended that a prototype be constructed to test the garment for its intended end use.

Individuals have many body shape differences and it is difficult, if not impossible, to take into account all the possible variations. Body shape plays a role in determining the fit of garments. Observation and judgment of the shapes and contours are the best tools when determining fit. However, it should be noted if the functional garment, or any of the items worn while performing the tasks required, change the posture of the individual. The individual may lean forward to offset the weight of a heavy item placed on their backs, such as a self-contained breathing apparatus or a tank filled with pesticides. True fit must be determined at the point of complete readiness to perform the job or function.

Once the general suitability of the garment is ascertained, trial testing by actual end users is suggested. A wrinkle analysis is considered a valid method of collecting data on the fit of a garment. Tight wrinkles indicate areas where more garment ease is needed for a particular movement. Areas, where the fabric hangs loose at all times, may need to have the amount of fabric reduced in that location. Pattern alterations are typically necessary in order to achieve good fit.

5 Adjustable and Flexible Fit

Since these garments need to fit people of varying sizes, adjustability may be an added requirement. Being able to alter the fit of the garment is important in order to have it function properly for an unknown population with a variety of body types and sizes. Functional clothing has a higher need for adjustability because the need for functional use is imperative. One way of achieving an alterable fit is to build in adjustability. Differences in width are easier to adjust than in length. The use of lacings, hook and loop tape, ties or other systems may prove beneficial in critical fit areas of the garment. This type of system can provide the opportunity for adjustability to fit a wider range of individuals.
A series of lacings, similar to a corset, can reduce the size of the garment and bring it closer to the body. This type of adjustability can be time consuming and may be used in conjunction with a second method, such as hook and loop tape. For example, the first time a garment is worn it can be laced to the body as needed. Subsequent uses would then only require the secondary method for donning and doffing. An example of this method would be the American football shoulder pad system; the closest shoulder size is chosen and the set of pads is fit to the body with lacings at the center front and center back. The padding system is then secured to the body with a strap that secures the back section to the front section around the chest. This strap is also adjustable to allow for ease in donning and doffing.

Elastic can also be used to allow adjustability in fit of protective garments or equipment. Shin guards, used in high impact sports such as ice hockey, have a rigid plastic front and elastic backs to allow the guard to fit snugly in place but allow for movement of the athlete.

Adjustments can be built in to the design of the garment. An example of a length adjustment could be the use of pleats, held closed with hook and loop tape or long stitches, which can be opened to allow for extra length in the sleeves or leg of pants. While analysing chemical protection garments, it has been found that many participants use duct tape to secure the garment to gloves and boots in order to create a fully enclosed environment from head to toe. The tape is also used to reduce the fullness of the garment around the arms and torso.

The use of separates, such as a jacket and trousers as opposed to using a jumpsuit, increases the range of individuals who can be served. There are numerous ways when the use of separates could help fit. For example, many people wear one size on the top part of their body and a much larger or smaller size on the bottom. Having separates available would enable them to choose the size closest to what they need to achieve a level of fit. For some functions, having separates is not appropriate, such as total containment suits which must provide a protective barrier between the wearer and the environment. In this instance, a one piece jumpsuit style would be more protective and outweigh the benefits of separates.

Other fasteners could also be used to provide adjustability in fit. A series of buttons with a variety of buttonholes at different locations, hook and eyes, buckles and straps, rows of snaps and even separating zippers are all options to consider.

6 Conclusion

Fit is considered successful in protective clothing when the needs of the wearer are achieved along with the required functionality of the garments. This is a delicate balance to achieve.

Depending on the requirements of the situation, functional clothing could be a simple layer of fabric or a very complex and multi-layered system. Whichever it may be, fit of the garment to the individual in order to allow for the garment to function as designed and for the individual to work as required is of great importance and one of the biggest challenges faced. In order to provide sufficient protection, the performance of the individual may be altered or hampered. This balance must be continually assessed throughout the design and fitting process.

References