Seams for Protective Clothing—An Overview

Shanthi Radhakrishnan¹,* and Devendra Kumari²

¹Department of Fashion Technology, Kumaraguru College of Technology, Tamil Nadu, India
²VCMM Arts and Science College for Women, Tamil Nadu, India

Abstract: Specialized clothing is essential for protection against specific environments like fire, heat, cold, chemical, mechanical and biological in nature. Specialized clothing that has been designed and fabricated to face the challenges of these environments is Protective Clothing which is a combination of functional design and functional focus. Seams are most important structures that help to keep a garment intact; they must be strong and have many qualities to hold the garment together in extreme conditions. The type and nature of thread, the model of seam construction and the testing of seams are important for the performance of protective clothing as one loose thread or gap in seams can unravel the space between the person and the environment leaving the person vulnerable. Seams for protective clothing play a critical role since they directly affect the integrity of providing protection, leading to death of the individual. In this paper the different seam construction methods used for protective clothing is being analyzed.

Keywords: Protective clothing, specialized environment, ultrasonic seams, seam taping and glueing.

1. INTRODUCTION

Protective clothing comes under the technical textile category or products. While all clothing is protective to some degree, concern is not with routine needs, such as clothing for warmth, rainwear or routine work clothing. The focus today is on more sophisticated needs, protection in situations where hazards or risks are present that have the potential to be life threatening or pose considerable potential for injury or damage to the person working in and around the hazard. In some cases, such as clean rooms, the concern is about protecting the product as well as the worker. Many of the new advanced "high-tech" fibers and fabrics are used in protective clothing. Conventional materials such as nylon and polyester, cotton and wool, are also used and provide satisfactory protection in certain applications - depending on the hazard or exposure. When new fibers with unique properties are being developed, they are often considered for protective clothing [1].

Classifying personal protective textiles is complicated because no single classification can clearly summarize all kinds of protection. Overlap of the definitions is common since there are so many occupations and applications that even the same class of protective clothing often has different requirements in technique and protection. Depending on the end use, personal protective textiles can be classified as industrial protective textiles, agricultural protective textiles, military protective textiles, civilian protective textiles, medical protective textiles, sports protective textiles and space protective textiles. Personal protective textiles can be further classified according to the end-use functions such as thermal (cold) protection, flame protection, chemical protection, mechanical impact protection, radiation protection, biological protection, electrical protection and wearer visibility [2]. Examples of protective clothing for different end users are given in Figure 1.

2. CONVENTIONAL SEWING

Modern day sewing machines are highly automated and programmable and can form seams at very high speeds. However, the basic mechanism of stitch formation remains similar to that created during the late nineteenth century - that of interlacing threads through or around textile materials. Stitch formation involves the carrying of needle thread to the reverse side of the fabric, where it is interlaced or interlooped with the under threads. The process is made continuous by a mechanism that feeds the material over a defined distance, through the needle head. When a stitch is used with a defined geometry of fabric positioning, a seam is formed [8]. Standard classification of stitches and seams is available in international standards, as given below:

- ISO 4915, 1991-08 (Stitch types -classification and terminology).
- ISO 4916, 1991-09 (Seam types -classification and terminology).
- BS 3870 Part 1 (Stitches and seams -classification and terminology of stitch types).
- BS 3870 Part 2 (Stitches and seams -classification and terminology of seam types) [9].
3. SEAMS FOR PROTECTIVE CLOTHING CATEGORIES

Seams are very important in the case of any type of apparel or clothing. It serves the function of converting a two dimensional cut fabric into a three dimensional garment. In the case of protective clothing they must also serve the function of resistance to the environmental features which might cause harm to the human body. Based on the end use, the seams used for protective clothing are Serged Seam, Sewn and Bound Seam and Heat Sealed Seam. Serged seams are used for a dry environment, sewn and bound seams are used for light liquid background and heat sealed seams for liquid splash and as a barrier to chemical environment, as expressed in Figure 2. The seams suitable for chemical protective clothing, medical protective clothing, protective clothing against cold weather, protective clothing against fire and heat and defense protective clothing are discussed herewith.

3.1. Seams for Chemical Protective Clothing

Seams may also be bound or reinforced with other material pieces such as additional fabric or tape or even covered with a top coating of a polymer. The type of seam and how it is applied is usually affected by the material used in garment construction and the intended integrity or performance of the chemical protective clothing [2]. Different types of seam constructions can be used in protective clothing categories such as serged seam, bound seam, sewn seam with tape seal on one side, sewn seam with tape seal on both sides, glued and sealed seams. However, lap or fell seams are also used in the fabrication of some Protective Clothing.

![Figure 1: Types of Protective Clothing based on end use: (a) Chemical protective suit (b) Cold protective suit (c) Biological Protective suit (d) Mechanical Protective Suit (e) Fire and Heat Protective suit [3-7].](image1)

![Figure 2: Seam Types for Special Environments: (a) Dry Environment (b) Liquid & Chemical Environment (c) Light Liquid.](image2)
The seam types for chemical protective clothing include. (Figure 3)

3.1.1. Serged Seam

A serged seam joins two pieces of material with a thread that interlocks. This is an economical stitching method for general applications. This stitching method is generally not used for all types of chemical protective clothing. It is more commonly found on limited use in dry particulate protective clothing where dry particles are of concern. An example of a serged seam is given in Figure 4(a). Apart from serged seams, lap or fell seams may also be used.

3.1.2. Bound Seam

Stitched seams produces stitched holes that provides a path to chemical penetration. The bound seam limits the pathways for chemical penetration as the seam is wrapped with a folded strip of similar or stronger material and chain-stitched through all five layers in a single operation. These operations result in a tougher seam which also provides improved liquid and particle repellency at the seams as well as a tougher garment all round. A bound seam is not suitable for a chemical suit as it is not liquid tight. Figure 4(b) shows the bound seam.

3.1.3. Stitched and Taped Seam

The seam is first stitched and sealed on the outside with a heat activated tape. This results in an impervious seam which is completely liquid-tight. As these seams are generally used for chemical suits the tape type is often constructed from a similar material to the garment fabric in order to maintain similar chemical permeation properties. When the heat sealing is done on both sides with a heat activated tape the seam becomes fully impervious and is considered to be the strongest seam for gas-tight suits e.g. Interceptor [14]. Figure 5 shows the flat felled seam (LSc -1) with heat sealing tape on one side (5a) and heat sealing tape on top and bottom sides of seam (5b).

Figure 3: Seam Construction for Chemical Protective Clothing [10].

Figure 4: (a) Serged seam EFd; (b) Bound seam BSa-1 [11 & 12, 13].

Figure 5: Stitched and taped seam: (a) Stitched & Single Taped Seam; (b) Stitched & Double-Taped Seam [11, 15].
3.1.4. Glued Seam

Adhesive films like Sewfree are being used to replace stitches for seams. Primarily components of garments namely pockets, zippers, darts, pleats, hemlines were constructed using glued seams. Hems and plackets are also being glued to provide a clean look, eliminate the use of seam tape and prevent water leakage in the used areas e.g. Hems, pocket flaps or cuffs. The purpose of glueing in garments is to provide significant improvements in garment weight, softness, breathability and comfort. Heat and pressure may be used to activate the adhesive in the films which creates a bond between the adjoining fabrics. Gluing is usually performed for coated fabrics and unsupported rubber materials; the woven fabric is coated with rubber or plastic on one or both sides of the fabric. Some of the materials include PVC/Nylon, Polyurethane Nylon, Neoprene/Nomex and Butyl/Nylon [16]. The method of layering the materials for a glued seam is shown in Figure 6.

3.1.5. Sealing

Sealing is applied to materials where the surface can be melted to create a bond with the surface of another material as shown in Figure 7a. This seaming approach is used for plastic laminates, thermoplastics, and other film-based materials [2]. Sealing can be accomplished by using ultrasonic welding machine, Radio Frequency Welding, hot air welding, hot wedge welding, Laser Welding and Bonding Technology [9]. The equipment used for welding and hot wedge welding are shown in Figure 7(b) and (c). Ultrasonic technology involves the creation and channeling of high frequency vibratory waves that cause rapid heat to

---

**Figure 6:** Glued Seam: (a) Material layering for glued seam; (b) Coated fabrics [17].

**Figure 7:** (a) Sealing method, (b) Welding equipment, (c) hot wedge welding equipment [9].

**Figure 8:** (a) Seamsonic machine for ultrasonic seams, (b) Nonwoven welded seam, (c) Ultrasonic welding-pleated fabric [20, 21].
weld or bond synthetic fabrics [18]. These methods are adhesive free and time for drying glues or solvents can be avoided. Clean look, water proofing and less weight are the advantages when compared to a garment with regular seams.

3.2. Seams for Biological Protective Clothing

Non-woven seam sealing tapes are used for Medical Protective Clothing, Anti-bacterial Protective Clothing and other Non-woven fabric products. Protective garments are generally useless without strong, tight seams. The protective suit must have the highest level of non-penetrable seam construction for biohazard applications to ensure there is no penetration of blood-borne pathogens. Types of seams recommended for use in biohazard medical applications are Heat Sealed/Taped Seams, Ultrasonic Seam. Hot air seam sealing machine and the ultrasonic generator with converter are generally used for heat sealing and ultrasonic sealing respectively. (Figure 8)

The electronic conversion of the line voltage into a high voltage/high frequency signal is made by an ultrasonic generator which is delivered to a converter. The converter has piezoelectric crystals placed between two titanium discs that vibrate at the frequency of the applied electric signal. This; vibration produces a fast mechanical movement of 20,000 cycles per second with small amplitude of about 18 microns. This can be further increased with an amplitude coupler. The resultant amplitude causes compression and friction between the thermoplastic molecules causing heating and melting of the material which creates a bond between them. This method of seaming or welding creates a superior particular and fluid barrier [19].

3.3. Seams for Cold Weather Protective Clothing

Seam sealing is an important step as total sealing of clothing is required for protection from cold weather. Waterproof tape seals the seams to prevent any moisture from leaking in through the needle holes made when stitching the material together. Critically taped seams will cover the most exposed sections of the seams, while fully taped seams will seal every stitch on the garment [11]. Initially the suits used traditional sewing methods to simply overlap two strips of rubber and sew them together. This technique had many problems as the punched holes through the two overlapping strips of foam or rubber opens the suit to water flow causing discomfort. The second problem was the stretching of the material which enlarged the needle holes when the suit was used by the personnel. These discrepancies made the protective clothing to be very cold along the seams and the seam became a perforated tear edge causing wearing of the suit along the seams during use. When nylon-backed neoprene appeared, the problem of the needle weakening the foam was solved, but the needle holes leaked water along the seams.

3.3.1. Seam Taping

To deal with the early sewing problems, taping of seams was developed. The tape is a strong nylon cloth with a very thin but solid waterproof rubber backing. The tape is applied across the seam and bonded either with a chemical solvent or with a hot rolling heat-sealer to melt the tape into the neoprene. With this technology, the suit could be sewn and then taped, and the tape would cover the sewing holes as well as providing some extra strength to prevent tearing along the needle holes. Figure 9(a) is an example of seam tape sealed protective clothing.
3.3.2. Seam Gluing

Another alternative to sewing was to glue the edges of the suit together [Figure 9c]. This created a smooth, flat surface that did not necessarily need taping, but foam glued to foam is prone to tearing as the bond is not strong. Most early wetsuits were fabricated completely by hand, which could lead to sizing errors in the cutting of the foam sheeting. If the cut edges did not align correctly or the gluing was not done well, water leakage along the seam is inevitable. Initially suits could be found as being sewn/glued/taped only, then sewn and taped, or glued and taped, or perhaps all three.

The blind stitch method was used to sew nylon-backed neoprene. A blind stitch sewing machine uses a very unusual curved needle, which is designed to not go all the way through the neoprene but just shallowly dip in behind the fabric backing as shown in Figure 9(b). The curved needle allows the fabric backing to be sewn together without punching a hole completely through the neoprene, and thereby eliminating the water-leakage holes along the seam. Blind stitch seams also lay flat, butting up the edge of one sheet against another, allowing the material to lay flatter and closer to the skin. For these reasons blind stitching rapidly became the primary method of sewing wetsuits together, with other methods used mainly for decorative or stylistic purposes [23].

The seam tape is activated by hot air seam sealing machine, and applied to sewn seams of the coated fabrics to prevent water from leaking through the seams. The machines used for seam sealing are Hot-Air Welding Machines or Ultrasonic Wave Welding Apparatuses and the type of products using the seam sealing techniques are ski jackets, functional clothing, diving suits, raincoats, tents, any winter waterproof clothing & products of TPU, PU and PVC coating fabrics [25]. (Figure 10)

3.4. Seams for Heat and Fire Protective Clothing

The seams for heat and fire protective clothing are serged seam (Figure 11a), bound seam (Figure 11b), and the sealed seam (Figure 11c). A surged seam is produced when three threads are interlocked around the raw edges of two pieces for a strong, stress-resistant seam. A bound seam is tightly sewn with a reinforced outer binding to increase seam strength and barrier for potential light splash of nonhazardous liquids.
or particle penetration through the seam. A sealed seam is produced when materials are lapped and thermally welded with no fillers, thread or needle holes.

The National Fire Protection Association (NFPA) has devised performance manufacturing standards for chemical and fire protective clothing. The stitch type 401, 301 and 504 while seam classes superimposed seam type 1.01 and lapped seam 2.02 is used for fire protective clothing as shown in Figure 12a, b, c, d and e respectively [23].

3.5. Seams For Mechanical Protective Clothing

Composite laminate armour or hard armour consists of multilayered fabrics combined together with a resin binder. Usually the hard armor, Spectra Shield, does not require sewing as its panels are usually just cut and stacked in layers that go into tight fitting pouches in the vest. A bulletproof vest made from Kevlar can be either quilt-stitched or box-stitched. Quilt-stitching forms small diamonds of cloth separated by stitching, whereas box stitching forms a large single box in the middle of the vest. Quilt-stitching is more labor intensive and difficult, and it provides a stiff panel that is hard to shift away from vulnerable areas. Box-stitching, on the other hand, is fast and easy and allows the free movement of the vest [25].

Body armor is used for protection by law enforcement and military personnel, Secret Service agents, emergency responders and CIA and IRS employees. Bullet-proof materials like Spectra-Shield and Kevlar–contained in the vest lose their life-saving effectiveness when exposed to water and hence it is absolutely critical that the seams in the outer nylon shell are perfectly fuse. Ultrasonic bonding creates a strong molecular bond that is impervious to moisture and eliminates stitch holes, glue gaps, fraying and unraveling, reducing risk of damage to the interior contents of the vest. Ultrasonic bonding occurs when woven or nonwoven synthetic materials or blends with up to 40% natural fibers are placed between the machine’s horn and anvil or, in the case of the Seam Master, rotating wheel. High-frequency vibrations result in localized heat buildup that causes the synthetic fibres to soften and fuse, creating a durable seal without needles, thread, glue or other consumables. The sealing of seams are very critical in such situations especially when life is exposed to serious risk [29].

CONCLUSION

Seams are the most essential connections in protective clothing and must be flexible and durable for producing two or three dimensional products. The sewing thread should also possess qualities that must maintain the demanding requirement of the entire product. Products in this sector are high-tech, innovative and special keeping the main focus on function. Hence seams are very special and sometimes the life of personnel depend on these seams; if seams fall apart the life of the personnel wearing the protective clothing will be in danger. Hence exceptional care must be taken to select the parameters to construct the seam and to decide the method of construction to maintain the durability and safety of protective clothing. Much research and testing is carried out to improve the functions and performance of seams. Standard procedures are available to test seams as their performance is of utmost importance while selecting the appropriate method of construction to develop a protective suit or technical apparel.

REFERENCES


Seams for Protective Clothing—An Overview


Received on 20-12-2017 Accepted on 28-12-2017 Published on 31-12-2017

© 2017 Radhakrishnan and Kumari; Licensee Synchro Publisher. This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0/), which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.