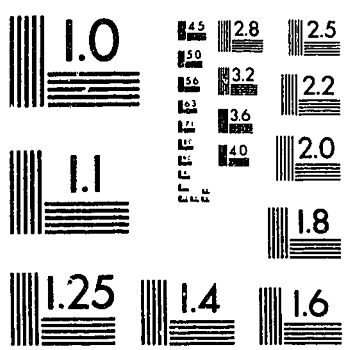
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UNIVERSITY OF ALBERTA

DEVELOPMENT OF A CUSTOMIZED PATTERN DRAFTING SYSTEM FOR INTERIM BURNSCAR PRESSURE GARMENTS UTILIZING FABRIC PROPERTIES AND CIRCUMFERENCE MEASUREMENTS

BY

LAURIE ANN BOONE ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled DEVELOPMENT OF A CUSTOMIZED PATTERN DRAFTING SYSTEM FOR INTERIM BURNSCAR PRESSURE GARMENTS UTILIZING FABRIC PROPERTIES AND CIRCUMFERENCE MEASUREMENTS submitted by Laurie A. Boone in partial fulfillment of the requirements for the degree of Master of Science in Clothing and Textiles.

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Date: January 30, 1995

ABSTRACT

Development of a Customized Pattern Drafting
System for Interim Burnscar Pressure Garments
Utilizing Fabric Properties and Circumference Measurements

by

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Pressure garments are utilized to treat burns by applying pressure to maturing burnscar tissue, decreasing hypertrophic scarring. This study focused on developing a pattern drafting system using fabric properties and circumference measurements to apply the required pressure for interim burnscar pressure garments. Tension and other characteristics of three selected fabrics were determined following standard or modified textile test methods. La Place's Law ($P = {}^{T}/_{R}$) served as the basis for the drafting system, choosing hypothetical body measurements for the formula. With body radius and desired pressure known, required fabric tension was easily determined using the formula. Using this value and a graph of tension versus percent elongation, garment sizes were calculated. La Place's Law was shown to be useful in determining appropriate sizes of cylindrical pressure garments.

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Lastly, I would like to express my appreciation to my parents, Mary Ellen and Graham for their continued support and encouragement throughout my graduate studies. Their kind thoughts will always be remembered.

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CHAPTER I

INTRODUCTION

In recent years, medical advances have been made in the area of rehabilitation for individuals who have been thermally injured. Advancements made in the initial analysis and treatment of thermal injuries have increased the survival rate of burn victims. For those involved in caring for these individuals, this means dealing with patients who have complicated injuries and subsequently need more care-giving and emotional support. Occupational therapists and plastic surgeons are involved in the care of burn survivors once the burn wound closes. Early and aggressive treatment is required to reduce the scarring and allow the formation of flat scar tissue. If the burns are deep and cover much of the total body surface, scarring cannot be avoided, but the serious effects of it can be decreased.

One of the most disfiguring accidents that can befall a human being is a burn to the body. Methods of burn treatment have taken various directions in the past but have converged to focus on pressure therapy. By utilizing various materials such as padding, splints and pressure garments, occupational therapists strive to achieve the flattest and whitest scar possible.

Thermal injury is one of the most traumatic because of the time needed for recovery, the excruciating pain involved, and the disfigurement that can occur. The seriousness of scarring as the patient heals can be diminished through the appropriate use of splints, proper positioning of joints, and the use of pressure garments (Carr-Collins, 1992; Kischer, Shetlar, & Shetlar, 1975; Malick & Carr, 1982). To understand treatment of the thermally injured, it is important to consider: normal skin function, burn classifications, hypertrophic scarring and its origins, and psychological problems faced by burn patients. With such understanding, one can better appreciate the measures taken in returning a burn patient to as normal a life as is possible- cosmetically, emotionally and physically.

Currently, burn units around the world use pressure garments to treat burn patients. Pressure garments are generally made of either a spandex/nylon or a cotton/rubber combination in a knit construction. Designed to fit like a second skin, the garment exerts pressure over the maturing scar tissue. Pressure garments are produced both commercially and at burn units with the goal of applying 25mm Hg pressure to the scar tissue. This pressure exceeds intercapillary pressure and is thought to provide the best results. If left to heal on their own, maturing scars will shorten and contract, causing the skin to become lumpy and limiting the range of motion of the affected limb. Researchers have found that through the application of pressure directly onto the maturing scar, satisfactory results can be achieved if the patient complies with the treatment program (Malick & Carr, 1982).

The use of pressure for treating burnscars is not new. Approximately twenty years ago, Dr. Silverstein, a medical doctor, unknowingly discovered pressure garments' usefulness in treating thermal injury. He was treating a patient who had burns to the legs and abdomen. The patient was wearing a vascular support garment (similar to present day pressure garments) on one leg for postphlebitic syndrome and a girdle for abdominal support. The physician noticed that the scar on the uncovered leg was raised and red as was expected of a burnscar. However, the scar on the covered leg had a smooth and flat appearance. Around this same time, a well known physician from the Shriner's Burns Institute in Galveston observed the same effect when splints (also having a pressure-exertion quality), were applied to burnscar tissue (Jobst, 1990). Thus, research into the use of pressure therapy for treating thermal injury began.

Statement of the Problem

Many burn units construct their own pressure garments both for interim and long-term use, rather than purchasing them from commercial manufacturers. Therapists strive to treat patients as soon as their wounds close and the new skin can tolerate pressure.

Generally, there is a four to six week delay between the time of ordering and subsequently receiving the custom garment. To compensate for the delay and to begin pressure therapy as soon as possible, technicians make interim pressure garments at burn units because this ensures quick alterations to the garments and greatly reduces the costs involved. Alternatively, tubular bandages available in various circumferences are used to treat the limbs and these are stored at the burn unit.

An individual is measured for a custom garment as soon as the wound heals and an order is then sent to the manufacturer. While waiting for a custom garment, the patient is released from the hospital and may return home to regular meals and exercise. During this period a decrease in edema (swelling) is experienced and often this results in a change in body dimensions. Frequently, there is then a need for alterations to the pressure garments when they arrive. The pressure garments must then be returned with the specified changes, resulting in another delay in treatment. Custom garments tend to be costly because of the technology involved. As well, two sets of garments are required so one can be washed while the other is worn, adding to the expense.

It is critical to begin pressure therapy as soon as the wound closes, but this usually occurs while the custom garments are on order. As an interim treatment, pressure is applied by using either a standard-sized interim garment, tubular bandages or custom-made interim garments produced by hospital technicians. The problem addressed in this study was to develop a pattern drafting system for customizing interim pressure garments for burnscar treatment, by utilizing fabric properties and body dimensions.

Justification

Historically, home economics/human ecology has focused on the well-being of individuals and families. Disciplines drawn on by home economics include biology, sociology, psychology, anthropology, and environmental design and planning, among others. With such a multidisciplinary nature, many interesting areas of study have been pursued and acknowledged as research in home economics/human ecology.

The Association of Administrators of Home Economics (AAHE) identified five major research goals for home economics in a 1970 research workshop. Two are especially relevant to this research project and are as follows:

> ***Goal I:*** *Improve the conditions contributing to people's psychological and social development*
>
> ***Goal II:*** *Improve the conditions contributing to people's physiological health and development*
>
> (Touliatos & Compton, 1988)

An individual's appearance may affect his or her self-concept and, thus, plays a role in the mental well-being of that person. Research into burnscar management should lead to improvements in current interim pressure treatment practices, enhancing benefits of pressure therapy. If favourable results can be maximized through earlier treatment of burnscars, improvements in burn patients' physical appearance and subsequently their self-concept may be realized. It is anticipated that the information obtained in this project will be of benefit to burn units and occupational therapy departments, while adding to the knowledge of fabrics suitable for pressure garments.

Objectives

The objectives of this study were as follows:

1. to follow a functional design process, to develop a method of drafting patterns for interim pressure garments utilizing fabric properties and body circumference measurements;

2. to determine relevant characteristics and specific performance properties of three types of fabric; and

3. to evaluate the pattern drafting system for garment pressure achieved, using a specially developed pressure monitoring device.

Definitions

For the purposes of this study, the following definitions apply:

hypertrophic scar- red, raised, gnarled and tough scar tissue, often seen in whorl-like patterns.

hysteresis- a measure of the energy loss which occurs between loading (stretching) and unloading (relaxing) (Jobst, 1990).

La Place's Law- pressure on the limb equals the tension (per segment of elastic pressure support) divided by the radius of curvature (of the limb).

permanent set- is a measure of the increase in fabric length resulting from cyclic stretching and relaxing.

permeability- the flow rate of fluid under a differential pressure through a fabric.

pressure garment- elastic garment designed to apply pressure to a maturing burnscar and aid in the development of smooth, white scar tissue.

stress decay- is the decrease in tensile force that occurs when an elastic fabric is held in an extended state.

tricot knit- a warp knit having each needle supplied with a yarn and all needles knit at the same time, producing a complete course. This warp knit variation is composed of only knit stitches with wales seen on the technical face and a crow's foot appearance seen on the back due to the underlaps (Hatch, 1993).

weft knit (tubular knit)- a knitted fabric in which the yarn producing the loops in the fabric is carried across the width of the fabric, that is, in the crosswise direction (Joseph, 1986).

Limitations

1. As the study was conducted within the economic means of the researcher, a limited selection of fabrics were evaluated and it is possible that more fabric structures are suitable for interim pressure garments.
2. Full tension testing was conducted at only one degree of extension due to time constraints.
3. Because test conditions were above standard conditions due to technical problems, test results may not be easily replicated.

Outline of the Thesis

Chapter II comprises a summary of literature related to this research: thermal injury, hypertrophic scarring, pressure therapy, and the psychology of burn patients. Chapter III outlines the functional design process. The basic process is described and is followed by an in-depth description of its use in this study. Results of the earlier steps of the functional design process are discussed in Chapter III as part of the step-by-step process. Chapter IV is devoted to the results of the last two steps of the functional design process, the prototype development and evaluation of the pattern drafting system. Discussion of these results and how the testing relates back to the objectives of the study are also included. A summary of the study, conclusions and recommendations for future research are presented in Chapter V.

CHAPTER II

REVIEW OF LITERATURE

Much literature has been published on pressure therapy techniques, pressure garments, the psychological aspects involved in burn patient rehabilitation, and the physiological changes that occur when the skin is thermally injured. An understanding of these areas is essential when discussing the treatment of a burn patient. The topics discussed in this chapter are burn classifications, burn treatment, hypertrophic scarring, pressure therapy, pressure treatment aids, pressure garments, scar maceration, pressure monitoring, and the psychology of the burn patient. The functional design process will be reviewed and addressed in chapter three to familiarize the reader with the steps involved. The project utilized selected steps of the process to develop the prototypes for evaluation. The process has been modified to fit the project.

Thermal Injury

Reaction of the Skin to Thermal Injury

The skin is the largest organ of the body and it serves many important functions (Lawrence, 1982; Malick & Carr, 1982; Trotter & Johnson, 1979). These include protection from fluid loss and fluid entry, sensation, regulation of temperature and blood pressure, and production and storage of vitamins C and D. The skin also protects against infection, eliminates waste products, and aids in establishing an individual's identity. Normal skin is composed of two main layers -the epidermis and the dermis (Hole, 1992). The epidermis is the thin outer layer and contains no blood vessels. The dermis contains a network of blood vessels, nerves, hair follicles, sweat glands, and the epithelial elements which regenerate the skin. It is this layer that contains the nerve endings where the sensations of pain, temperature, and touch are relayed.

A loss of a large area of skin, as in the case of severe burn, deprives the body of its protective functions and leaves the injured patient very vulnerable. Infection is easier when the skin is damaged and there is danger of bacterial contamination leading to systemic infection (Malick & Carr, 1982; Wise, 1984). In the case of a severe burn, the mechanisms regulating body temperature and elimination of waste products can be stressed to the point where they fail, resulting in illness (Trotter & Johnson, 1979). When the burn covers a large area of the body, excessive fluid loss can be potentially life threatening and can lead to difficulties in controlling body temperature. A burn may also expose nerve endings, resulting in extreme pain and hypersensitivity. It is possible for a second degree burn to evolve into a third degree burn if it becomes infected. A deeper burn involving the full dermal layer can deprive the body of sensory perception until the nerves are regenerated (Malick & Carr, 1982).

Burn Classification

In the past, it was common to classify burns as first, second, third or fourth degree depending on the depth of the thermal injury. Now, it is more common to use terms which more accurately classify the burn. These terms are partial thickness burn (including superficial partial thickness and deep partial thickness) and full thickness burn (Malick & Carr, 1982; Slome, 1961). A fourth degree burn is known as an electrical burn and will not be discussed in this paper.

A superficial partial thickness burn involves the epidermal and some portions of the upper dermal layer (depending on the severity of the burn). The nerve endings are exposed, and because sensation is not damaged, the wound is extremely painful. This type of burn usually closes within 14 days and skin grafting is unnecessary (Malick & Carr, 1982). A deep partial thickness burn affects the entire epidermis and the dermis to a greater degree. Sensation with this type of burn is variable. Pressure is easily detected by the patient but light touch and a pinprick would not be. Full thickness burns destroy the full epidermal and dermal layers, including the hair follicles, nerve endings and epithelial elements. If deep enough, the fat layer can be affected, destroying the sweat glands as well. With this severe type of burn, the patient initially feels no pain because the nerve endings are destroyed (Malick & Carr, 1982).

The severity of the thermal injury depends on the age and past medical history of the patient (Trotter & Johnson, 1979). Patients under 2 years and over 60 years of age experience the highest mortality rate compared to other age groups with similar injuries. Stress on the heart, other injuries present, and current deficiencies in general health and nutrition all contribute to the problem. The reaction of the patient emotionally and intellectually can lead to increased stress on the body and affect the way the patient responds to appropriate care instructions.

Burn Treatment

When treating a thermally injured patient, it is necessary to estimate the severity of the injury. The depth of a burn combined with information about the total amount of body surface affected by that depth of burn is used to estimate its severity (Trotter & Johnson, 1979). For example in initial care, an individual with 50% total body surface area (TBSA) burned would require more fluids than a person with a 5% TBSA burned. Initial treatment of a burn patient is very important as it will affect the rate of the individual's recovery.

As cited by Malick and Carr (1982), Pulaski and Tennison developed the Rule of 9's which describes a burn injury in relation to the TBSA. They divided the body into percentages or multiples of nine and assigned a specific value to each body part. These percentages change depending on the age of the patient, whether infant, toddler or adult (Malick & Carr, 1982; Rose & Deitch, 1983; Rose & Deitch 1985). For example, the percentage TBSA of the head of an infant under one year of age is 18%, whereas for an adult it is only 9% .

Body areas are divided into percentages as follows:

	Adult	One Year Old (Child)
Head and neck	9%	18%
Each upper extremity	9%	9%
Anterior trunk	18%	18%
Posterior trunk	18%	18%
Each lower extremity 18%	14%	
Perineum	1%	

Hypertrophic Scar

Hypertrophic scar formation is expected following a deep thermal injury such as deep partial thickness and full thickness burns (Ward, Hayes-Lundy, Reddy, Brockway & Mills, 1992). When the wound first closes and the edema has diminished, fresh scar tissue develops. It is flat, warm, red and smooth at this point but dramatic changes will take place if proper treatment is not given (Larson, Abston, Evans, Dobrkovsky, & Linares, 1971). The formation of the scar is the "structure" of the healing burn. If left to form without opposition, it will thicken and contract, restricting movements and disfiguring the patient (Carr-Collins, 1992). Hypertrophic scarring will occur anywhere, except areas that are attached to underlying structures (scalp, palms of hands, soles of feet, and the tip of the nose) (Ng, 1989). Research has found that the longer a burn wound remains open, there is an increased expectancy of severe scarring (Deitch, Wheelahan, Rose, Clothier, & Cotter, 1983; Garner, 1987).

When the wound contracts, the skin essentially shrinks and restricts range of motion if the burn affects a joint (Trusler, Glanz, & Bauer, 1953). Often, if this occurs, the body appears deformed because joints are held at positions that do not appear normal. New connective tissue (fibroblasts) forms and collagen (a fibrous protein) is deposited at an accelerated rate due to increased vascular flow to the area (Wise, 1984). Researchers have found this collagen production rate to be from two to eight times the regular rate (Malick & Carr, 1982; Rose & Deitch, 1983). There is no overall orientation as thick bands of collagen mix with thin collagenous fibres. As a result, whorl-like patterns and nodules form which are quite dissimilar to the parallel patterns found in normal skin (Malick & Carr, 1982).

The fibroblasts develop features similar to those found in smooth muscle cells giving the scar tissue contractile properties. Myofibroblasts are modified fibroblasts found in the granulation tissue of hypertrophic scarring and are thought to contribute to the production of contractures (Jensen & Parshley, 1984). This means that the scar will pull on adjacent structures, shortening the wound and making it responsible for the deformities and contractures characteristic of hypertrophic scarring (Huang, Blackwell, & Lewis, 1978; Malick & Carr, 1982). For about 18 months, or until scar maturation is complete, the scar becomes thicker, more rigid and contracts (McLaughlin, 1990). This gives the scar varying textures with some areas raised 4mm or greater (Judge, May, & DeClement, 1984).

Through treatment and research, it has been found that the degree of scarring is somewhat dependent on skin colour. It has been found that darker skin colours are prone to more severe scarring and require longer treatments than lighter skin colours (Alhady & Sivanantharajah, 1969; Allan & Keen, 1954; Peacock, Madden, & Trier, 1970). Keloids (severe, very raised, discoloured hypertrophic scarring) often disfigure the patient and generally need surgery to reduce their size (Kitlowski, 1953).

As mentioned, researchers have found that hypertrophic scars and contractures are best treated through the application of pressure (Martyn, 1990; Rose & Deitch, 1984). Until the scar matures, it is malleable and the application of pressure to the skin's surface significantly decreases the amount of scarring (Martyn, 1990; McLaughlin, 1990). The physiological changes caused by pressure are better understood now than they were twenty years ago when pressure therapy gained widespread use.

Pressure Therapy

Background to Pressure Therapy

Pressure is applied through the use of pressure garments, splints and inserts. It has been found that the best results are obtained through the aggressive and early use of these modalities (Carr-Collins, 1992; Bruster & Pullium, 1983; Judge et al., 1984; Kischer et al., 1975; Larson, 1974). The amount of pressure required to achieve a more functional and cosmetically pleasing scar is somewhat controversial and ranges from 4 to 55 mm Hg (Leung, Cheng, Ma, Clark & Leung, 1984; Martyn, 1990; Rose & Deitch, 1985). In general, it is believed that the pressure must exceed capillary pressure which is 20 mm Hg. Denton (1972), indicated that when garment pressure is similar to blood pressure in the capillaries near the skin surface, the garment is considered to be uncomfortable.

Through the use of pressure, the whorl-like and nodular formations change or are prevented from forming, resulting in re-orientation of the collagen fibres to elongated patterns. The elevation and redness of the scar decreases because of this re-orientation and reduced blood flow to the area (Kischer et al., 1975; Malick & Carr, 1982). It has been found that pressure therapy accelerates the natural healing process, and scars subjected to continuous pressure for as little as one month show improvement (Malick & Carr, 1982).

The pressure exerted on the scar tissue must continue until it matures in order for the therapy to be effective. Scar maturation with pressure therapy is the progressive remodelling of the scar. It becomes softer, flatter, and the tension decreases around the edges of the wound. As a result, the scar has a more acceptable appearance and it is much less disfiguring.

The skin is very sensitive when the burn wound first closes. Because of its delicate nature the skin cannot stand extremely high pressures initially. Researchers suggest that the optimum level of pressure is 10-20 mm Hg on a new scar. If pressure exceeds this, the skin is likely to shear which can lead to infection (Judge et al., 1984; Rose & Deitch, 1985). As the scar matures, the pressure applied to it can be increased to achieve the best results. Therefore, several different pressure garments are required through the course of treatment.

Pressure Treatment Aids

There are a number of products available that are used to treat burn patients for hypertrophic scarring. These include Ace® wraps, pressure garments, padded inserts, splints, elastomer molds and Uvex® face molds. Each has its advantages and disadvantages. In general, the main problem faced by those treating burn patients is the difficulty in achieving uniform pressure over various parts of the body. The most difficult areas to treat with pressure are the face, hands, axilla (underarm area), neck, and groin because of their dynamic features (Leman, 1992; Malick & Carr, 1982; Rose & Deitch, 1985). Therefore, the proper fit and design of these devices are very important if they are to achieve maximum results.

An initial method of applying pressure is by the use of Ace® wraps, which are essentially tensor bandages (Bruster & Pullium, 1983). It is very difficult to gage the pressure applied with this method because the pressure varies depending on who applies the wrap. Therefore, specific and consistent pressure cannot be achieved and problems are encountered when the wrap slips with movement (Malick & Carr, 1982).

The most commonly used pressure garments are Tubigrip®, Bio-Concepts® and Jobst®. Tubigrip® comes in two forms, either a ready-made standard sized garment or a tube which is available in various widths. Tubigrip® products are made from a cotton and rubber knit fabric (Rose & Deitch, 1983). Bio-Concepts® and Jobst® garments are custom-made from nylon and lycra knits using a powernet construction. They require accurate measurements of the patient before manufacturing the garment to obtain the appropriate pressure and correct size. Therefore, there is no way of stocking the garments at the burn unit. However, Jobst® garments are more uniform in pressure than standard sized garments because they are made from specific body measurements, making them ideal for long-term treatment (Malick & Carr, 1982). Cheng, Evans, Leung, Clark, Choy and Leung (1984), indicated that lycra was the most commonly used elastic material for pressure garments. An important consideration is the choice of fabric which influences how the pattern is developed (Johnson, 1987).

Tubigrip® is applied in the early stages of scar maturation due to its availability at the burn unit and its reasonable cost (Susan Illmeyer OT, personal communication, Nov. 1992). Kealy, Jensen, Laubenthal and Lewis (1990), compared Tubigrip® and Jobst® pressure garments for burnscar treatment. They found that both were equally effective in treating burn patients but patients were more compliant in wearing Tubigrip® due to its ease of use and comfort. Tubigrip® was also found to be more economical than Jobst® at a garment wholesale cost of $232.00 compared to $433.00 for the latter.

Tubigrip® is frequently used as interim garments after skin grafting and while patients wait for their custom garments. Rose and Deitch (1985), found that Tubigrip® could be successfully utilized for the entire treatment because it allowed for immediate alterations as a patient's body size changed (especially children's). Tubigrip® can also be used on unhealed areas whereas Bio-Concepts® and Jobst® garments were found to be too harsh for use in these tender areas. Often, initial pressure treatment begins with the use of Tubigrip® while custom garments are on order because it takes at least four to six weeks to receive a custom garment back from the manufacturer. Since better results are achieved through early application of pressure to scar tissue, Tubigrip® treatment is often begun as soon as the newly closed wound can tolerate pressure. While waiting for custom garments, the patient is often released from the hospital and begins to do more exercise and eat normally. This often means a gain in weight for the patient, altering the body dimensions and subsequently the custom garment needs further adjustment. Alterations are also required since a patient is first measured for their pressure garments while still experiencing edema. While patients wait for their long-term care pressure garments, this swelling decreases which further alters body dimensions.

As mentioned, an accurate fit is a major problem with both interim and long-term care pressure garments. Often, the garments bridge concave areas of the body resulting in uneven pressure and even zero pressure in some areas. Padding is usually added to increase pressure in areas such as the palm of the hand, underarm and spinal region.

Padding and inserts include various substances and involve several techniques (Carr-Collins, 1992; Fujimori, Hiramoto, & Ofuji, ,1968; Malick & Carr, 1980, 1982). Silicone patches are basically elastomer sandwiched between two layers of Tubigrip®. They are made by first applying a layer of Tubigrip® over the scar, than the elastomer is added and another layer of Tubigrip® is placed on top. The elastomer conforms to the shape of the body scar and a pressure garment is then worn over top of the patch to exert pressure on the area (Van den Kerckhove, Boeckx, & Kochuyt, 1991). The fit and design of inserts are important to prevent additional problems such as blistering and shearing. The insert must be easy for the patient to use and positioned properly to achieve satisfactory results. If an insert is difficult to use, a patient is not as likely to comply with using it (Malick & Carr, 1982). This same principle applies to pressure garments.

Splints are used in combination with pressure garments to minimize scar formation and contractures. Splints are generally made of a low temperature thermoplastic and are designed to keep limbs and digits in optimum positions. The use of splints starts early after a patient is admitted in order to prevent healing in a dysfunctional position (Leman, 1992; Malick, 1975). Early splinting not only controls edema but also immobilizes affected joints in functional and protective positions. This is important so that a full range of motion can be realized while the patient's scar tissue matures. A patient whose full range of motion is limited due to a contracture, can become very frustrated (Ward et al., 1992).

Clear plastic face masks (Uvex®) are often used when remodelling the face after thermal injury (Gallagher, Goldfarb, Slater, & Rogosky-Grassi, 1990; Malick & Carr. 1984). The mask is held in place by elastic straps that can be adjusted to increase or decrease t[illegible] pressure applied. Without intervention, eating, oral hygiene, dental care, and most im[illegible]ial expressions can be seriously affected adding to a patient's frustration [illegible]; Malick & Carr, 1982). The semi-rigid plastic applies the pressure nee[illegible]uce severe scar build up. Pressure garments made from a powernet fabric with stretc[illegible] all directions tend to present problems when used on the face. Uneven pressure can result from the holes cut out for the eyes, nose, mouth and ears.

Uniform pressure cannot be achieved when holes are cut in the elastic fabric (Malick & Carr, 1982). Due to the fact that the face is so hard to treat with pressure because of its dynamic features, problems can arise. Too much pressure on the chin, especially in children, can cause a recessed lower jaw which can lead to physical and social problems (King, Blomberg, & Pegg, 1994).

Characteristics of Pressure Garments

The success of pressure garments depends on the fit and on patient compliance, both of which must be carefully monitored to determine when replacements are necessary (Carr-Collins, 1992). Pressure garments must be worn continuously for one to two years or until the scar matures, so garment replacement is necessary. The selection of the garment design is influenced by a number of factors: burn location, graft and donor site location, [illegible] the healing burn, and the tensile strength of the maturing scar.

For the garment to be effective, it must extend 50 to 75 centimetres beyond the edge of the burn to ensure adequate pressure on the healing scar tissue(Carr-Collins, 1992; Malick & Carr, 1982). Generally, the garment should cover all areas that require pressure. Therefore, garments are specifically designed for the location of the burn and the stage of the scar in the healing process.

Pressure garments are available in various configurations, either with or without zippers (Blair, 1977; Malick & Carr, 1982). Velcro® is not used frequently since it tends to buckle and can be difficult to launder due to garment snagging. However, Velcro® can be found in children's garments to accommodate growth expansion and to position inserts in both adult and children's garments. Some variables for garment design are sleeve length (full or half), zipper placement, type of fabric, style of the axillary area, glove designs and linings. Carr-Collins (1992) recommended that the first set of garments for a patient should have zippers in order to allow the patient to dress independently. Zippers also reduce the amount of shearing and friction on newly healed areas.

Sleeve length is very important when choosing a garment style for the patient. For example, if a burn involves one arm and the chest, the pressure garment should have one full sleeve (on the burned arm) and one partial sleeve. This style is called a vest and must always have a combination of full or partial sleeves (never sleeveless) to balance the tension across the upper chest (Malick & Carr, 1982). Open axillas (armpit seams) can be included in the garment design if the underarm area is fragile and cannot tolerate pressure. The purpose of this design is to provide pressure as soon as possible to the other areas that require it. Pressure treatment should not be withheld until all burn sites have healed over, rather it should be applied as soon as the new skin can tolerate pressure.

The neckline is another important area of consideration and various designs are available depending on where the burn is located. When there are no burns to the upper trunk, a regular scoop neck is used, for a more comfortable garment. If burns are present on the chest or back, a regular round neck is specified. Burns extending to the anterior surface of the neck require a turtle neck design and a collar must be worn to achieve an optimum amount of pressure (Carr-Collins, 1992; Malick & Carr, 1982).

A glove design is used when treating hypertrophic scarring on the hands. The hand is an exposed part of the body and any disfigurement can result in stigmatization of the burned individual (Bernstein, O'Connell & Chedekel, 1992). Open fingertips are considered whenever possible to permit tactile sensation. Therapists have found that patients are less likely to remove pressure gloves when they do not interfere with daily activities (Susan Illmeyer, OT, personal communication, Nov. 1992). Soft linings are also available for pressure garments to help reduce friction and decrease the chance of scar breakdown over tender areas such as the joints.

Scar Maceration

Scar maceration (breakdown) may be encountered upon the initial application of pressure (Carr-Collins, 1992). When the scar first forms, the epithelium is thin and fragile making the area highly sensitive to friction. Monitoring the maturing scar is very important to reduce the risk of infection and re-opening of the wound. The therapist plays a very important role throughout treatment in preventing infections that can lead to further complications. Early signs of scar maceration include bruising of the scar, distal edema if the pressure garment is too tig'.t, pain and blistering. This can be corrected by altering the fit of the pressure garment (Carr-Collins, 1992).

Scar breakdown can also occur due to other factors. Friction can occur between the garment and the scar (point pressure), especially around the joints and in body creases. As mentioned, linings can aid in the prevention of scar breakdown. Poor hygiene poses another problem. Patients must be made aware that washing their garments daily is necessary to prevent infection (Malick & Carr, 1982).

Custom-made pressure garments tend to be more of a problem for patients in warm weather because of the nature of the material used. Nylon provides little comfort to the patient because it does not wick much perspiration from the skin. As a result, perspiration builds up and can contribute to infection. This phenomenon can also occur when splints and elastomer are used. Using powder and removing the splints occasionally reduces the chance of infection (Malick & Carr, 1982). Patients with deep full thickness burns may lose the use of their sweat glands, thereby limiting thermal regulation. As a result, the patient experiences excessive heat build up and has no means of releasing it. This makes the pressure garment extremely uncomfortable and reduces patient compliance. One of the most frequently encountered problems with pressure garments has been found to be itching, although this decreased as scar tissue normalized (Kloti & Pochon, 1982).

Pressure Monitoring

Quantitative verification of the correct pressure applied by pressure garments on maturing burn scars is difficult to obtain (Harries & Pegg, 1989). A wide range of pressure values can be obtained using different garments and on various body parts. Pressure readings are influenced by soft body tissue, the geometry of the body, and movement. Pressure transducers utilized to monitor pressures achieved by pressure garments are not well developed (Harries & Pegg, 1989; Ng, 1989). Ng stated that there is a need for a suitable pressure transducer to monitor static pressure and instantaneous interface pressure variations with limb movement. Often, pressure is checked subjectively at burn treatment centres by inserting two fingers between the garment and skin or by gripping the seam and pulling it away from the body, noting resistance.

Psychology and the Burn Patient

A person who is thermally injured, goes through a number of stages before recovering emotionally from the trauma involved. Some patients never fully recover emotionally even with extensive counselling (Bernstein et al., 1992). In the acute (initial) phase the patient is calm and has little awareness of his or her surroundings (Malick & Carr, 1982). Often, the patient is annoyed at having to miss work or being away from his or her family. Emotional shock sets in after this and nightmares of the events leading to hospitalization are often experienced. In the intermediate stage, which can last from a few weeks to several months, extreme physical pain dominates the patient's life.

Bernstein et al. (1992) found that to resume normal life after a major burn injury, a person must maintain a sense of hope for the future. The after effects of a burn, such as the loss of pleasure and pain sensations, and scarring can impair an individual's return to society (Trotter & Johnson, 1979). As well, the patient is filled with apprehension about the future with respect to scarring, disfigurement, distortion of body image, and doubts about resuming a normal life (Straten & Mahler, 1984).

Kaiser (1985), stated that a person's self-concept is "derived and maintained through social interactions with others". According to Bernstein et al. (1992), one's self-concept is based on body image and bodily feeling. For a person with a disfiguring burn, especially when highly visible areas such as the face or hands are involved, it can be difficult to maintain a healthy concept of self. Negative public reaction to disfigurement caused by burns is a major problem faced by those recovering. Not only does the patient have to internalize his or her own feelings about the injury, but the patient must deal with the outside world as well. Often, people who are disfigured by burns withdraw and disappear socially so they will not have to deal with public reaction (Bernstein et al., 1992; Malick & Carr, 1982).

Throughout recovery, family and friends are very important to the patient. Full support will lead to a speedy emotional recovery. Fear of deformity and loss of function are very frightening for the patient, especially when a lengthy hospitalization is involved. With the support of family and counselling, it has been possible for many burn patients to recover emotionally from their injuries (Bernstein et al., 1992).

Psychiatrists and other health care professionals play an important role in the treatment of burn patients. They are not only required in a long-term support role and during hospitalization, but also in the acute or initial stage of the treatment of burn patients. Though they are rarely required immediately after the individual is hospitalized, they should familiarize themselves with the events leading to the traumatic event. In the early phase of treatment, the psychiatrist is required to calm or even sedate the patient and to explain medical procedures that the patient is undergoing. Later, when splinting and traction begin, the psychiatrist must repeat many explanations of procedures and ensure that the patient gets plenty of rest and sleep. Reassurance is often necessary as patients doubt the effectiveness of various treatments because results take a long time to become evident.

Summary

To summarize, much research has been conducted in the area of pressure therapy and various methods of treatment. From the review of literature, it is apparent that a gap in the research exists. Little published research has been conducted on the fabrics utilized for constructing pressure garments. Different fabric properties are exhibited due to their structure and fibre content. These properties affect the end product, but past research has failed to address this issue. The actual design of pressure garments to apply a specific pressure has not be well-documented. The relationship between body dimensions and the garment dimensions, and the resulting pressure applied due to the difference in circumference needs to be addressed. It is apparent that occupational therapists assume that customized pressure garments are applying the required 25mm Hg of pressure.

Researchers have identified the optimum amount of pressure necessary for treatment, but have not discussed how customized pressure garments are designed.

CHAPTER III

FUNCTIONAL DESIGN PROCESS

The functional design process is a self-organizing approach to design that combines the creative process with strategy control. Functional apparel is clothing that is designed to meet the physical, social, psychological, and aesthetic needs of potential users (Van Schoor, 1989). The main objective is to meet the specific needs of a given population. The process takes the designer from the initial idea through to the evaluation of the final design. Within the framework, there are various strategies from which the designer can choose to fit a design project (DeJonge, 1984).

A problem solving approach is utilized in functional design. The goal is to design a garment that meets established design criteria such as allowing full mobility to perform required tasks while wearing the garment. DeJonge (1984) stated that the functional design process was based on the work of Jones (1970) and was further adapted to clothing design. Concern had developed that designers needed to pay more attention to the effect clothing had on its wearer. This concern was the catalyst for the application of the functional design process to clothing.

Jones (1980), described three different views of designing. The first view is that the designer is a "Black Box". This approach to design is creative and all designing takes place in the designer's head. This viewpoint of design has an inherently mystic quality to it. "Designers as Glass Boxes" is Jones' second view of designing. While being more rational, it is concerned with externalized thinking. In theory, the design process is to be explicable, though this is not always the case in practice. Designers may not be able to give convincing reasons for the decisions that they make.

The third view of designing sees the designer as a "self-organizing system". This allows the designer to see in himself or herself,

> "the degree to which the search actions decided upon do, or do not, produce an acceptable balance between the new design, the situations influenced by the design, and the cost of designing (Jones, 1970, p.55)."

The self-organizing view applies to the functional design process (DeJonge, 1984). This view comes closest to combining the creative approach with strategy control because it clearly defines the pieces of the problem which are integrated into a holistic, creative and effective solution.

For the present study, the functional design aspect of the work will be the development of a pattern drafting method for producing interim burnscar pressure garments utilizing fabric properties and body circumference measurements. Adequate fit allowing for full mobility and comfort, while very important, are beyond the scope of this study. Rather, ideal pressure application will be the focus as it is important to garment and pressure treatment usefulness.. Adaptations will be made to aspects of the functional design process to fit the present study.

Functional Design Process: Overview

The functional design process is described here in a general overview. Initially, the designer must become familiar with the potential user population. Research includes knowledge of the needs of the wearer, consisting of everyday activities, care for the clothing and any environmental factors that may affect the performance of the garment.

After the initial search, specific activity assessments are conducted to identify the critical factors more closely associated with the design problems (DeJonge, 1984). Though movement is usually assessed, the nature of the garments under investigation in this study are such that this would be a never-ending task. Nevertheless, the garment must allow for full mobility when it is worn or it will not be worn at all.. A person wearing a pressure garment is encouraged to return to work and lead a normal life. Hence, every aspect of daily life would have to be assessed.

The number of factors and the extent to which they are assessed vary with the problem being investigated. Following careful observation of the critical factors, detailed design specifications are formulated. Finally, the designer sets priorities among conflicting specifications, thereby establishing design criteria. Prototypes are then developed from the specifications and, in ideal situations, are evaluated by potential users.

Operational Functional Clothing Design Process

Figure 1 summarizes the functional design process operationalized for the present study. Various strategies were selected and will be discussed as they relate to the project. Development of a pattern drafting system was based on this process.

General Request

The purpose of this functional clothing design project was to generate a customized design system for developing interim pressure garments to treat individuals with thermal injuries, using fabric properties and physical body measurements.

Exploration of the Design Situation

Literature Reviewed

In Chapter II, literature on the skin, hypertrophic scarring, pressure garments, and the psychology of the burn patient were reviewed. It was apparent that one standard-sized interim garment, such as those produced by Tubigrip® and Jobst®, would not be suitable to treat the various shapes and sizes of thermally injured individuals. Therefore, it was deemed appropriate to work on a design system that customized these interim pressure garments through the analysis of both the inherent fabric properties and use of client measurements.

GENERAL REQUEST
custom pressure garments design system

EXPLORATION OF THE DESIGN SITUATION

Literature Search
(general terms)
-burn injury
-burn treatment
-hypertrophic scar
-pressure garments

Interview (focus group)
-interim pressure garments

Observation
-methods of pressure therapy
-pressure garments used
-tubular knits used

PROBLEM STRUCTURE PERCEIVED

Literature Search
(specific terms)
-stretch fabric
-La Place's Law
-designing with stretch knits
-on-site garment design

Material, Garment Usage
-powernet
-tubular knit
-pressure

Market Analysis
(manufacturers)
-custom pressure garments
-Jobst®/Bioconcepts®
-Tubigrip®

DESIGN CRITERIA

Functional Requirements
-comfort
-fit
-mobility
-pressure

Psychological Requirements
-comfort
-aesthetics

Pressure
-tension of fabric
-closeness of fit

PROTOTYPES DEVELOPED

Material Testing
-tension
-air permeability
-pilling resistance
-thickness & mass
-resistance of fabric to water vapour diffusion
-knitted fabric count

Testing Evaluation
-results of textile testing
-averages where applicable

Custom Drafting System
-use of tension
-La Place's Law

DESIGN EVALUATION

Pressure Application
-effective pressure range 12-15mm Hg
-circumference measurements reduced for garments to achieve pressure
-reductions based on tension data

Evaluation
-pressure monitoring device

Figure 1. **Functional Clothing Design Process for Interim Pressure Garments Study**

Focus Group Interview

At this second stage of the functional design process, wearers were observed in action and inconsistencies and obvious problems with existing garments identified. To aid in the identification of garment problems, a focus group interview was conducted with four individuals who had been thermally injured and who had worn a tubular knit for the interim treatment. The purpose of this interview was to gather individuals together, focus on their interim burnscar treatment and obtain information on their experiences during this phase of recovery.

Usually, three or more focus groups containing eight to ten participants are recommended. However, due to the small population of thermally injured people available, a narrow focus group was conducted. This interview took place December 2, 1993, at the Alberta Burn Rehabilitation Society office, in Edmonton, Alberta. Subjects had been referred to the researcher through the president of the above society.

Participants were members of the Alberta Burn Rehabilitation Society and either had entirely recovered from their thermal injuries or were still wearing long-term care pressure garments. All four individuals had sustained their injuries within the last four years. Two were injured in 1992 in a gas-well explosion and two were injured in 1990 in separate accidents. All participants had worn tubular knit bandages for the interim phase of their treatment while awaiting their long-term care garments. The length of interim pressure garment treatment ranged from one to three months.

A sample consent form and interview guide used in the focus group interview can be found in Appendices 1 and 2 respectively. Subjects were asked to recall their interim treatment and to write down positive and negative aspects of that treatment. The respondents were then asked to discuss these aspects with the researcher who recorded the responses. The participants were then asked specific questions regarding the various interim treatments that were utilized. Standard-sized interim garments, tubular bandages, and custom-made interim garments were all included in the focus group interview as they all have been discussed in the literature as appropriate methods of interim treatment.

From the informal interview, garment problems were identified. The four burn patients in the focus group had worn only the tubular bandages during the interim phase and found them to be very warm. No information on the other two types of treatment was gathered from this interview due to the limited sample available for the focus group. Three subjects had worn the tubular knit in the summer which may have contributed to the warmth. The problem of overheating was partly attributed to damaged sweat glands and, subsequently, impaired body temperature regulation. Another problem with the tubular bandages was that they tended to stretch out of shape and many respondents found that the raw edges frayed and required frequent trimming.

Tubular bandages were available in various circumferences suitable only for the limbs at the burn unit where the subjects were treated. The participants felt that a vest or torso garment would be very appropriate to use in conjunction with the tubes so pressure therapy on all areas of the body could be initiated sooner. In one case, a subject required two different sizes of tubes to adequately apply pressure to his legs (larger tubes for the thighs and smaller tubes for the lower legs). These tubes generally overlapped one another by about 75 mm instead of being seamed together to join them. Some end slippage occurred where the tubes overlapped. Occupational therapists often had to alter the tubes by constructing seams to achieve a better fit and contour the arm or leg where necessary.

Clinical Treatment Observations

At the University of Alberta Hospital, patients are initially treated with tubular support bandages. In some instances, a technician makes up a torso pressure garment to be worn during this period. The interim tubes or garments are worn until the custom-made supports from either Jobst® or Bioconcepts® arrive. Splinting and inserts are utilized in combination with the custom pressure garments to prevent contractures and to increase pressure in areas of need. Either a custom made mask from one of the garment manufacturers or a Uvex® face mask is recommended for thermal injuries of the face.

Through the exploration of the design situation, three areas of consideration were identified: garment design needs, activities of the wearer, and problems with existing garments (Figure 2). Past experience of those who have undergone interim burnscar treatment is relevant as problems with existing garments can be identified. Comfort, in terms of fit, breathability, and psychological comfort, plays an important role in the recovery process. When the pressure garment fits and allows for full mobility, the client is more likely to wear the garment as recommended. Clients are also less likely to wear the prescribed pressure garment if it is aesthetically unappealing and makes the injury conspicuous.

Problem Structure Perceived

At this point of the functional design process, more specific areas of literature were searched as they relate to each area of consideration. La Place's Law, stretch fabrics, designing with stretch fabrics and methods of pattern drafting burnscar pressure garments were investigated. The materials utilized in the construction of both interim and long-term pressure garments were researched and will be discussed with respect to fabric and garment properties. Pressure garments currently used by the University of Alberta Hospitals Burn Unit are discussed and manufacturers identified.

La Place's Law ($P= {}^{T} / {}_{R}$) states that the pressure exerted on a cylinder is equal to the tension of the fabric divided by the radius of the curvature (Bio-Concepts, 1991; Jobst, 1990). In ideal situations, the pressure would be equalized around the body, as in the case of a perfect cylinder. However, the human body has a non-cylindrical shape and has concave areas that cause various degrees of pressure when treated with a pressure garment. With the torso, for example, the greatest pressure is exerted on the sides and minimum pressure is exerted in the spinal and frontal regions. Inserts are used to pad these concave areas between the skin and pressure garment, making them more cylindrical in shape and thus increasing the pressure exerted in these areas.

Garment Design Needs

- washable
- comfortable
- aesthetically acceptable
- allows for full mobility
- easy to don and doff
- suitable for customization
- idea of soft garment appealing though little sensation in some cases

Activities of the Wearer

- donning and doffing
- daily activities (varied)

Problems with Existing Garments

- lose elasticity
- too hot
- abrasive on outer garments
- initial treatment with tubes on legs/arms only
- edges not stable
- don't apply enough pressure
- somewhat hard to keep clean due to light colour
- tubes slipped from functional position

Figure 2. Exploration of the Design Situation: Initial Considerations

Large pressure garment manufacturers such as Jobst* and Bioconcepts* utilize the principle of La Place's Law to achieve optimal pressure, but the specific application of the formula is not disclosed. Apparently, circumference measurements are used to determine the radius. Although the limbs are not cylindrical, average radii are utilized in the formula. Generally, it is believed that La Place's Law provides a more accurate method of producing the patterns for the long-term care burnscar pressure garments than simple percent reductions of circumference measurements (Ng, 1989).

Garments that are made from stretch fabrics are designed on the principle of negative ease. Negative ease is the difference between the body measurements and the garment measurements. To achieve the desired fit, a stretch garment is designed to be smaller than the body's measurements. This same principle is used in the design of pressure garments where the amount of negative ease incorporated determines the pressure exerted on the maturing burnscar. By simply reducing a garment or pattern by the wearing ease, and neglecting the amount of stretch in a fabric, deformations in key areas of the garment can occur (e.g. bust and hip areas). Therefore, the difference between body size and garment size must be controlled in order for the garment to effectively exert a specified pressure.

It is quite common for staff in burn units of a hospital to produce their own pressure garments for either interim or long-term use, or both. Pressure garments are produced on-site at burn units around the world, including England, Hong Kong, Switzerland, Australia, the United States and Canada. Though the methods for producing pressure garments vary from unit to unit, depending on the experience of those individuals involved in garment production, the goal of pressure application is the same. In some cities such as Toronto and San Diego, small privately-owned pressure garment manufacturers are directly involved with burn units and work closely with those treating the patient. At other locations, technicians make pressure garments and necessary adjustments for the patients right at the hospital site.

Parkland Memorial Hospital Burn Unit in Dallas, Texas, is one unit that produces its own pressure garments. The method of pattern drafting is quite basic and involves tracing the body parts that require pressure garments. These two-dimensional tracings serve as patterns for the pressure garments (Ng, 1989).

Omnimed, based in San Diego, California, works with the University of California San Diego Campus Hospital. The company has developed its own formula for producing patterns using a tricot knit fabric known as Naturexx®. Length measurements are reduced by five percent and circumference measurements are reduced by ten percent to achieve approximately 20 mm Hg pressure. Special rulers have been developed incorporating these reductions to facilitate pattern drafting. The amount of reduction and the pressure achieved was determined through experimentation with the fabric made into test garments and pressure measured using a pressure transducer (C. Sandlin, personal communication, Feb. 17, 1994).

The nylon and spandex fabric used by Omnimed is much softer and smoother than either Jobst® or Bioconcepts® fabrics. As well, Omnimed's tricot knit fabric, Naturexx®, has wicking properties to take moisture off the skin thereby increasing the client's comfort. Recovery Garment Centre, based in Toronto, uses the method developed by Omnimed. Garments at both locations are first made when the patient still has some edema. When this edema decreases, the garments are taken in. Therefore, interim garments are not required because the first garment helps to reduce the edema and then the garment is reduced in size (C. Sandlin, personal communication, Feb. 17, 1994).

Other burn units simply work on the basis of a certain percent reduction of the fabric or fabrics that they use. One medical unit initially reduces measurements by ten percent for interim treatment. Later, when the patient is ready for long-term care garments, circumference measurements are reduced by twenty percent to achieve the appropriate amount of pressure. However, garment openings at limb extremities require reductions to be held at ten percent to control edema and permit venous return (Ng, 1989).

Fabrics

There are two main types of fabrics used to construct burnscar pressure garments- tubular knits and powernets. The properties of these textiles vary considerably and, therefore, each is utilized in different capacities. In general, tubular knits are used for interim garments and powernets are used for long-term treatment since powernet fabrics have better holding power than tubular knits. Bio-Concepts®, which produce powernet garments, also provide soft linings and lining inserts of a different fabric when required. This fabric can be more readily stretched than the powernet and reduces friction wherever it is used.

The tubular knits used for burnscar treatment are composed of cotton and cotton wrapped rubber insertion yarns in a weft knit construction. The wrapped rubber yarn is laid in every fourth feeder in the knit fabric (Ng, 1989). The rubber insertion yarn provides elasticity, stability, and pressure. Due to the weft knit construction and the insertion yarns, the fabric stretches mainly in the crosswise direction (Joseph, 1986) and subsequently, the pressure is applied in this direction. Tubigrip® has greater extension than powernets and therefore requires fewer measurements for a proper fit (Ng, 1989). For this reason, it is more suitable than the powernet for the initial stages of treatment because its extensibility allows it to conform to the body without high pressures that can cause scar breakdown. Tubigrip® has also been utilized successfully for the entire period of treatment, including long-term (Kealey et al., 1990).

Powernets differ depending on the manufacturer, yarn texturizing involved, and the fibre composition used. In general, these fabrics have excellent memory and stretch capabilities. Jobst® produces its own powernet which is said to have tri-dimensional control because it uses unidirectional tension threads wrapped around prestressed fibres and caught in a bias lacing (Ng, 1989).

Largely, powernets are used where high power fabrics are required as in the case of a girdle. When they are used for burnscar treatment, they are light in weight and are approximately 60% porous (Jobst, 1990). Nylon and spandex combinations are the most frequently used fibres in a powernet fabric for burnscar treatment. Spandex has approximately twice the holding power of rubber, which makes it more suitable for long-term care garments. The unidirectional lay of the elastic yarns produces varying elastic properties at different angles which makes it hard to treat non-cylindrical surfaces. Most often, the powernet is fleshtone in colour, however Bio-Concepts® has made a wide variety of colours available ranging from bright yellow, to pink, blue, green and black.

Applied pressure is monitored in several ways. The most common methods employ the use of a pressure transducer that fits between the skin and the pressure garment (Cheng et al., 1984; Harries & Pegg, 1989). Although pressure readings are acquired, they are not accurate because the transducer distorts the shape of the curvature and subsequently the radius. Occupational therapists rely on their experience with pressure garments and simply determine if the pressure is adequate by inserting a finger between the garment and skin or trying to pinch up the fabric to check resistance. Research on pressure monitoring has been conducted, but presently there is no accurate transducer available that can be used to monitor the pressure achieved by a pressure garment (Ng, 1989).

Market Analysis

The two main custom pressure garment suppliers are Jobst® and Bio-Concepts®, both located in the United States. Both companies require a number of accurate measurements taken by an experienced occupational therapist to produce their pressure garments. The measurements are recorded on a series of charts and are sent to the manufacturer. Jobst® and Bio-Concepts® utilize special measuring tapes composed of a long spine with projections that wrap around the limb and are then secured in place with tape. Each company produces it's own measuring tape which differ in appearance but the two are similar in concept. Once wrapped around the body, the paper measuring tapes are cut off and measurements are recorded and sent to the manufacturing facility. Because clients are often measured for their long-term care garments while still experiencing edema, garments generally need alterations when they arrive. If returned to the manufacturer for alteration, another delay is experienced. The ramifications of these delays have been discussed previously. Often, occupational therapists make minor adjustments to avoid further delays in treatment.

Custom-made garments are available with options for the clients. Zipper length and placement can be specified by the person ordering the garment. Soft lining fabrics can be ordered from Bio-Concepts® for various regions of high friction like the axilla, elbow and knee. Bio-Concepts® also provides optional neckline styles depending on the location of the burn. This increases comfort for the patient and may facilitate patient compliance.

Interim pressure supports are produced by Jobst® and Tubigrip®. These companies supply both tubular knit bandages and standard-sized garments using a cotton and rubber weft-knit fabric. Raucopress®, available only in tubular form, is another similar fabric that is made in a weft-knit construction with a rubber insertion yarn.

Tubigrip® can be purchased in tubes of varying size. No pressure garment customization is available from Tubigrip®. A tension guide is located on the boxes of tubular knits to aid in size selection. A client generally wears one size of tube on the arm and another size on the leg, often with additional alterations. Tubigrip's standard-sized garments are seldom used due to the variation in size and shape of clients. When the standard-sized garments are tried on to check the fit, they become contaminated by the patient's wounds and dressings. If they do not fit, they cannot be used by another patient.

Design Criteria

The functional requirements for a pressure garment are very important for patient compliance and effectiveness of the pressure garment and design system (Figure 3). The garment must be worn for approximately 23 hours a day and, therefore, must not cause the wearer severe discomfort. As the garment must apply pressure to the skin, there will always be some discomfort experienced. Mobility should not be restricted and the garment must allow for the daily activities of the client.

Pressure

- interim pressure of 12-15 mm Hg
- maintained over period of interim treatment (4-6 weeks)
- must not interfere with healing process
- must not interfere with circulation

Fit

- fit like a second skin
- allow for full mobility
- style suitable for use with inserts
- comfortable

Fabric

- breathable
- elastic recovery
- washable
- not too warm
- adequate longevity

Design System

- must be customized
- utilize La Place's Law
- averaged radii from circumference measurements
- suitable to treat torso and limbs
- easy to use

Figure 3. Design Criteria for Interim Pressure Garments and Design System

Pressure applied by the garment is the most important criterion in the garment design. For long-term care pressure garments, pressure of approximately 25mm Hg is required for effective treatment of burnscar hypertrophy. Interim pressure garments generally have an effective pressure range from 12 to 15 mm Hg. To adequately treat maturing scar tissue, interim and long-term care garments must maintain pressure throughout their wear life. Therefore the type of fabric used for construction is crucial to the garment's longevity.

Fit is critical to the performance of a pressure garment. When it is too large, the benefits of pressure therapy will not be realized. In contrast, when the pressure garment is too small, the resulting high pressure puts the patient's health at risk. Scar maceration and restricted blood flow may lead to further medical problems. The design of a pressure garment is also important from a psychological perspective. When an individual is as comfortable as possible in the pressure garment, compliance is more likely to be achieved. If compliance with wearing the interim tubes or garments can be obtained, compliance with wearing the long-term garments may also be realized. Patients who faithfully wear interim garments are more accustomed to the pressures exerted by the garments and can better adapt to the increased pressures exerted by the long-term garments (Susan Illmeyer, personal communication, Nov. 1991).

When a garment is unobtrusive, the patient feels better. Often, a flesh-tone fabric is preferable as it attracts less attention. Long-term care pressure garments are constructed with small, flat-lock seams to minimize rough surfaces next to the skin, thereby reducing discomfort and enhancing garment appearance with a neat, flat finish. Generally, serged seams constructed on the outside are used on interim pressure garments. In some cases, clients may prefer coloured long-term care garments which are available from Bio-Concepts®. Children like bright colours because the garments appear similar to wearing tights and knit-wear. Thompson, Summers, Rampey-Dobbs, and Wheeler (1992), found that the public and those wearing pressure garments have positive feelings towards coloured pressure garments and this may lead to improving a patient's self-esteem.

The fabric used in garment construction must be breathable and not too warm to allow the wearer some comfort. It must also retain its shape and have elastic recovery in order to apply pressure after donning the garment. Because these garments are worn many times, the fabric(s) utilized to construct them must be entirely washable so body oils do not build up in them and lead to infection.

The development of a design system must take several factors into consideration. Customization of interim pressure garments is necessary for accurate pressure application. In order to achieve this, La Place's Law was explored along with fabric properties. In a real life situation, the human form is not perfectly cylindrical. However, circumference measurements can be taken and a "radius" determined. This concept is similar to one used by Jobst®.

Figure 4 illustrates the design specifications in a matrix form indicating where conflicts occur, and where accommodation between specifications is needed. Fabric properties varied for the different fabrics tested and therefore some accommodation among the design specifications was necessary. From the matrix, the reader can see that accommodation between several of the criteria is important in the final design of the interim pressure garment drafting system.

An accommodation must take place when considering design specification number one (application of 12 to 15 mm Hg) and design specification number three (not interfering with scar healing). It is possible that the application of this much pressure on a newly healed burn scar may cause it to break open and therefore less pressure would be required in this case. When considering design specifications 1 and 7, another accommodation is required. If a garment is to apply the required pressure, it may be extended to the point where elastic yarns break and not have any elastic recovery. In this case, either a different fabric should be chosen or a lower pressure obtained.

Areas of interaction (conflicts and compromises) among specifications are determined and once they are ranked, they become the final design criteria. As this study is intended to generate a pattern drafting system to customize interim pressure garments, the design specifications will not be discussed further. However, they may prove useful to further research in the area once actual prototype garments for clients are at the point of production.

Specifications	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. apply pressure of 12-15mm Hg		0	1	0	0	0	1	0	0	0	0	0	1	1
2. maintain pressure for garment life			1	0	0	0	0	0	0	0	0	0	0	0
3. not interfere with healing				1	0	0	0	0	0	0	0	0	0	0
4. fit like a second skin					1	1	0	0	0	1	0	0	0	0
5. comfortable						0	0	0	0	0	0	0	0	0
6. breathable							1	0	0	1	0	0	0	0
7. have elastic recovery								0	0	0	0	0	0	0
8. washable									0	0	0	0	0	0
9. be sewn on domestic sewing machine										0	0	0	0	0
10. absorb skin moisture											0	0	0	0
11. suitable for customization												0	0	0
12. utilize La Place's Law													0	0
13. have averaged radii used														0
14. be used to treat limbs														

KEY **0= no conflict**
1= accommodation
2= conflict

<u>Figure 4</u>. **Interaction Matrix of Criteria Representing Design Specification for an Interim Pressure Garment**

Prototypes Developed

The prototype development involved two processes - material testing and custom drafting system development. Once these portions were complete, the drafting system was evaluated theoretically by applying La Place's Law to the test results and by pressure monitoring to determine pressure achieved. Results of this evaluation are outlined and discussed in Chapter IV.

Textile Testing

The fabrics included in the study were Raucopress*, Tubigrip* and Naturexx*. These were considered suitable for interim pressure garments and were available to the researcher. The first two fabrics are tubular weft knits and are currently used at the University of Alberta's Burn Unit and the remaining fabric is a tricot knit used by Omnimed and Recovery Garment Centre.

Fabric properties were analyzed since they are critical to the development, wearability and comfort of interim pressure garments. Not only must the garment maintain pressure over time, but it must be comfortable and easy to care for. Index testing, including mass, thickness, and yarn count, was conducted to determine the inherent properties of the three different fabrics. Performance tests conducted included tension, dimensional change (determination of set), air permeability, resistance to water vapour diffusion and pilling resistance. Due to the specific application of the fabrics (burnscar pressure garments), some standard tests were followed as written, while other tests were modified to obtain the information desired. Modifications are indicated wherever appropriate.

Tension. The Instron tensile testing machine was used to determine tension at specified extensions, following a modified ASTM Designation: D 2964-89, Standard Test Methods for Tension and Elongation of Elastic Fabrics (Constant-Rate-of-Extension Type Tensile Testing Machine) (ASTM, 1989). U-shaped clamps were specially developed to test looped specimens on the apparatus. Tension testing involved two parts- determining load decay over time with repeated cycles and washing, and determining the load applied at specific extensions.

For the first round of tension testing, specimens were prepared according to the method except the length was 230 mm in the crosswise direction and 100 mm in the lengthwise. To test the crosswise stretch of the fabric, specimens were sewn together to form a loop with a circumference of 200 mm, leaving 30 mm for seam allowance. A double row of straight stitching, secured at the ends by backstitching, was used to sew the specimens.

Specimens were conditioned[1] and tested in a conditioning room. The tubular knits were held at 80% extension for a period of 23 hours and then washed and allowed to relax for 25 hours while another specimen was extended. Naturexx® specimens were held at only 10% extension for the same period of time because they were not as extensible as the first two fabrics.

Washing procedures were followed according to the instructions indicated on the package of Zero® and were as follows: a half capful of liquid Zero® detergent in one litre of water at approximately 20°C, specimens soaked for three minutes with the suds gently squeezed through, rinsed in cold water and laid flat to dry. Zero® was chosen because occupational therapists recommend the use of a mild detergent when washing pressure garments. Once dry, specimens were returned to the conditioning room to condition prior to extension.

The test cycle was chosen to simulate wearing conditions since a client would have two sets of garments, one to wear while the other one was laundered. Pressure garments are to be worn for 23 hours a day with one hour off for bathing purposes. Each specimen (four specimens per fabric sample) was extended through five cycles with load readings

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[1]All textile testing was conducted at 24°C±2 and 65%±2 RH which is above standard conditions (20°C±2 and 65%±2RH). This was due to malfunction of the conditioning room and beyond the control of the researcher.

taken hourly during the day. A chart recorder also recorded the load over time and load readings were determined every hour on the hour from the chart record.

It was thought that the load applied would change over time as a gradual realignment of intermolecular bonds within the elastic material occurred with cyclic stretching and relaxing (Dupont Canada, 1965). The change in load over time was graphed to help determine if permanent set and stress decay were significant. The tension testing provided information on how well each fabric maintained its elastic properties over time and how well such properties responded to washing.

For the second part of the tension testing, three specimens of each fabric sample were produced in the same manner except each measured 240 mm by 100 mm. Specimens were sewn as previously described to yield a specimen with a circumference of 220 mm. Tubigrip® and Raucopress® specimens were extended to 100% of their original length and held for one hour at which time the load applied by the specimen onto the equipment was recorded. The Instron's gauge length was then reduced by increments of 10% and after one minute elapsed (while load somewhat stabilized) load readings were again recorded. This information was useful in determining the tension of each fabric at various levels of extension.

Dimensional Change. CAN/CGSB-4.2 No. 58-M90, Colourfastness and Dimensional Change in Domestic Laundering of Textiles (CGSB, 1990), was adapted for testing shrinkage. Reference marks indicating an eight centimetre square box were marked by thread tracing on each tension specimen. These markings were measured at each end and in the middle for each direction to determine dimensional change and fabric growth. The specimens were measured half an hour after they were removed from the Instron and again prior to extension. This was done to determine how well the fabric maintained its shape after extension and recovery.

Structure. The structure of each of the three fabrics was determined using CAN/CGSB-4.2 No.7-M88, Knitted Fabric Count-- Wales and Courses per Centimetre

(CGSB, 1988). The closeness of the knit structure varies among the fabrics and this may have some effect on other fabric properties.

Thickness. Fabric thickness was determined for each fabric following CAN/CGSB-4.2 No.37-M87, Fabric Thickness (CGSB, 1987). Again, thickness may have some effect on other fabric properties and it is useful to have as much information as possible about the textiles under consideration. The thickness of the fabric may relate to the comfort of the garment, although wearing comfort is not being further investigated in this study.

Air Permeability. Individuals with thermal injury may have problems with thermal regulation since some of their sweat glands may be destroyed if the burn is deep enough. Keeping the patient cool and as comfortable as possible while wearing a pressure support is of prime concern for compliance. The focus group interview participants found the interim pressure garments to be quite warm. Some patients even removed the pressure garments if they found them to be too hot and uncomfortable.

When stretched over the body, fabrics become more porous and allow more air to circulate over the skin. This can have a cooling effect and may provide more comfort to the patient. The air permeability of the textiles was determined using an air permeability tester, following CAN/CGSB-4.2 No. 36-M89, Air Permeability (CGSB, 1989). Ideally, modifications should have been made to the test method so the specimens could be held under tension to simulate wearing conditions. As mentioned earlier, if a fabric is stretched it should provide a more porous structure and allow increased air flow. In theory, if a textile product is more permeable to air, it will be more comfortable. Due to time constraints, it was not possible to develop a frame which could be used to extend the specimens and, as a result, the test method was followed without modification.

Water Vapour Diffusion. Water vapour diffusion was determined for each of the fabrics under investigation following CAN/CGSB-4.2 No.49-M91, Water Vapour Diffusion (CGSB, 1991). This test was conducted according to the method specified because there were no means of conducting this test with specimens under tension. The rationale for conducting this test was that the property of water vapour diffusion is relevant because as water travels from the skin through the garment, it evaporates off the surface of the garment, permitting evaporative cooling. Water vapour diffuses from the skin into the fabric by two routes: a) between the yarns and between the fibres composing the yarns; and/or b) into and out of the fibres comprising the fabric, depending on the type of fibre present. When a fabric is permeable to water vapour, the water vapour makes its way to the fabric surface and diffuses into the environment (Hatch, 1993).

Since it is common for patients to sustain various depths of burns, not all sweat glands are destroyed. Therefore, the remaining glands function to control body temperature making water vapour transmission and air permeability of the fabrics important.

Pilling Resistance. The surface characteristics of the three knit textiles were determined using the brush pilling tester, following ASTM Designation: D 3511-82 Standard Test Method for Pilling Resistance and Other Related Surface Changes of Textile Fabrics, Brush Pilling Tester Method (ASTM, 1982). This test was done to simulate the garment rubbing on itself which, for example, might be experienced in the axillary area or the thighs. If a garment deteriorates rapidly in use, its other properties such as tension and dimensional stability may be diminished. This is not the most important textile property under consideration because interim garments are to be utilized for a short period of time (approximately four to six weeks).

In terms of pilling resistance, fabric specimens were rated according to the standards indicated in the test method. The appearance of the face of the fabrics were rated from one to five as follows:

5- no pilling
4- slight pilling
3- moderate pilling
2- severe pilling
1- very severe pilling

Interpretation of Test Results

The results of the tests provided information for characterizing each of the fabrics. As well, testing indicated some of the performance properties of the fabrics. The structure and properties of the fabrics were determined and this provided insight into their end use performance. For each of the above tests, results were recorded and compared.

Test results and a discussion of them are found in Chapter IV. Fabrics were not eliminated from the study based on their index and performance testing; rather the tests were used to provide comparison information about each fabric. All fabrics considered in the context of end use, however, must maintain their pressure over time. Properties such as air permeability, structure, and water vapour diffusion varied among the fabrics and these differences must be accommodated for when designing. An ideal fabric would be one that maintains pressure over time, is permeable to air, allows water vapour to diffuse through it and washes well.

Custom Drafting System

Utilizing tension data collected during the second part of tension testing, La Place's Law was applied to develop a custom pattern drafting system for the stretch fabrics investigated in this study. The pattern drafting system must be adaptable to any area of the body for it to be successful.

Fabric tensions varied with the degree of fabric extension. The more a fabric is stretched, the greater the resulting tension. In the tension measurements for this study, the maximum extension percent was 100% for Tubigrip® and Raucopress®. Naturexx®, because it was less readily able to stretch, was extended to a maximum of 20%[2].

The pressure range desired for the interim pressure garment was between 12 to 15 mm Hg. Pressures higher than this could cause discomfort and break open newly healed scar tissue. For this study, La Place's Law ($P = {}^{T}/_{R}$)was used to determine the garment

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[2] The fabric appears over-extended at 20% as results were not comparable to those from the 1st phase of tension testing.

size required to give the desired pressure. The desired pressure (P) of a mid-range value of 13 mm Hg is known and the radius (R) of the "body" can be calculated by measuring the limb circumference and using the formula $R={}^{2\Pi}/_{C}$. Solving for tension (T) gives T=PR. The percentage elongation for the garment can be determined by graphing the measurements of fabric tension versus percent elongation. The required garment radius can be determined as follows:

$$C_{garment} = 2\pi R_{garment} = 2\pi R_{body} /(1 + \%\ \text{elongation})$$

Evaluation of the Pattern Drafting System

Evaluation of the pressure applied by the prototype "garments" developed by this method was an objective of the study. Evaluation of the interim pressure garments was conducted by Capjack (1994), in an independent study in Mechanical Engineering, on a specially developed apparatus designed to monitor pressure (Figure 5). The equipment was utilized to measure the pressure of interim garments developed through the use of La Place's Law. Quantitative results indicated the accuracy or inaccuracy of the method of drafting.

The monitor consisted of an air filled balloon membrane connected to a validyne or pressure measuring device by a plastic capillary tube. The validyne was also connected to a power source and a voltmeter. The voltmeter was calibrated to the pressure range expected for the balloon, and the change in pressure due to the application of the fabric tube, was directly measured. This change in pressure was assumed to be the pressure applied by the specimens. The pressure inside the balloon was tested for a range of radii utilizing each of the fabrics. Three different radii were tested for each fabric and were as follows: 11.6 cm, 16.1 cm, and 17 cm for Raucopress®, 6.0 cm, 8.0 cm, and 9.0 cm for Tubigrip®, and 19.0 cm, 20.8 cm, and 25.2 cm for Naturexx® (Appendix 3). It was then determined if the measured pressure exerted by the garments was in an acceptable range for interim pressure treatment (12 to 15 mm Hg).

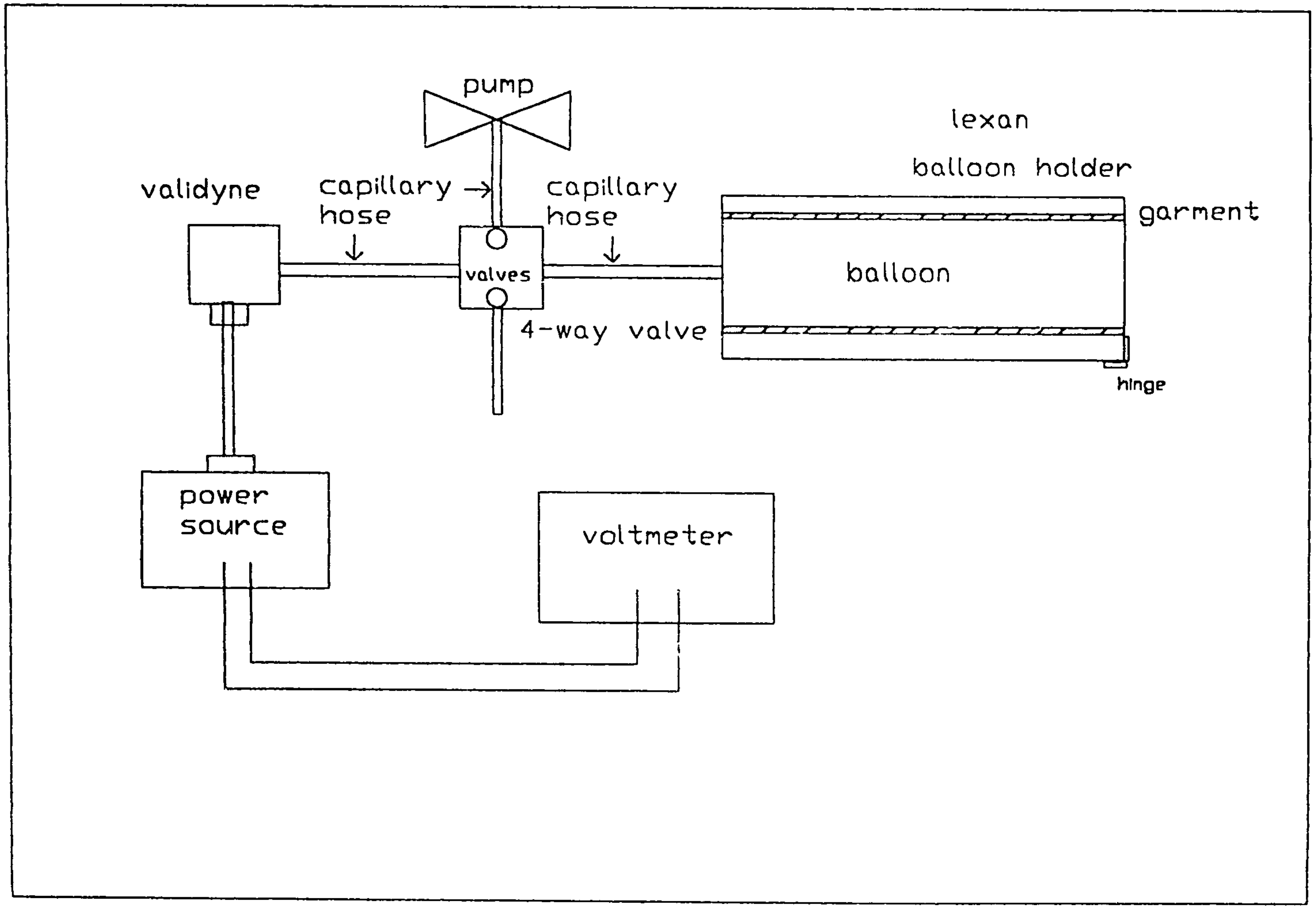

Figure 5. Experimental Schematic for Pressure Measurements

Each fabric was tested once by constructing prototype pressure garments and then testing them using the pressure monitor. Earlier testing on the Instron showed that load did not decay significantly over time between the first and fifth cycles for the fabrics so one cycle was chosen for this test. Garments were placed on the apparatus and the balloon was expanded. Pressure readings were taken and corresponding balloon and garment diameters were measured with calipers. Measurements were recorded as the balloon was expanded, deflated and re-inflated.

Tubes were tested only once with no washing and subsequently no load decay over time. Therefore, this pressure monitoring was expected to give results similar to the first extension on the Instron, with load decay to follow.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter describes the results of the final two steps of the Functional Design Process; Prototype Development and Evaluation of the Pattern Drafting System. The characterization of the three fabrics included in the study is based on the textile testing conducted. Inherent fabric properties are discussed in relation to the other textile testing results and fibre composition. Tension results are included in this chapter as they provided useful information for developing the pattern drafting system.

Results of pressure monitoring are also incorporated in this chapter as part of the final step of the Functional Design Process. Discussion of these results as they relate to the objectives identified in the first chapter of the study are included in this chapter.

Tension

The first objective of the study was to develop a method of drafting patterns for interim pressure garments utilizing fabric properties and body circumference. For the purposes of this study, hypothetical body circumferences were used and appropriate garment sizes were determined for the expected range of pressure. These were calculated based on the assumption that La Place's Law works and that the test results were the true behaviour of each fabric over various extensions.

For the first round of tension testing, the load for each fabric sample at the specified extension was determined by reading the load off the instrument and dividing by two because the specimens were tubular (looped). Load readings (Kgf) were taken for the initial load, after one minute, 30 minutes, one hour and hourly up to 23 hours for each of 5 cycles. From these results, means for 20 load "readings" (4 specimens 5 cycles) were calculated for the 26 time periods (Table 1). A fabric mean load was then

TABLE 1 LOAD MEANS[a] (n=4 specimens X 5 cycles = 20)

Reading Time	Raucopress (kgf)	Tubigrip (kgf)	Naturexx (kgf)
initial load	0.64	0.54	1.48
1 min. elapsed	0.56	0.50	1.17
30 minutes	0.51	0.48	1.03
1 Hour	0.50	0.47	1.01
2 Hours	0.49	0.47	1.02
3 Hours	0.48	0.46	1.01
4 Hours	0.48	0.46	1.01
5 Hours	0.48	0.46	1.04
6 Hours	0.47	0.46	1.01
7 Hours	0.47	0.46	1.00
8 Hours	0.47	0.45	1.01
9 Hours	0.47	0.45	0.99
10 Hours	0.47	0.45	0.98
11 Hours	0.46	0.45	0.97
12 Hours	0.46	0.45	0.94
13 Hours	0.46	0.45	0.92
14 Hours	0.46	0.45	0.92
15 Hours	0.46	0.45	0.92
16 Hours	0.46	0.45	0.91
17 Hours	0.46	0.45	0.91
18 Hours	0.46	0.45	0.91
19 Hours	0.46	0.45	0.91
20 Hours	0.46	0.45	0.91
21 Hours	0.46	0.45	0.91
22 Hours	0.45	0.45	0.92
23 Hours	0.45	0.45	0.91
Mean Load (Kgf)	0.46	0.45	0.96
Fabric Mean Tension[b]	45.60 N/M	44.20 N/M	93.70 N/M

[a] ASTM Designation: D 2964-89, Standard Test Methods for Tension and Elongation of Elastic Fabrics (Constant-Rate-of-Extension Type of Tensile Testing Machine)

[b] Fabric mean load X 9.81 ÷ .10 m

calculated by averaging all the hourly means from 1 hour to 23 hours. Fabric tension (N/M) was then calculated by multiplying the fabric mean load by 9.81 (to convert from Kgf to Newtons) and then dividing by the specimen width. At 10% extension, Naturexx® had an average tension over the 22 hour period of 93.7 N/M. Raucopress®, at 80% extension, had an average of 45.6 N/M while Tubigrip® had an average tension of 44.2 N/M at 80% extension.

The knitted yarn count for Raucopress® indicated a more densely knit fabric than for Tubigrip®. Both fabrics had a cotton wrapped rubber insertion yarn every fourth row. Raucopress® had rubber yarns inserted more closely to each other than Tubigrip®. Naturexx® had a higher tension value because it contains more elastic yarns per test area than the tubular knits. Raucopress® had a slightly higher tension value than Tubigrip® because it has more elastic yarns per test area.

Tubigrip® and Raucopress® both experienced stress decay over time as molecules within the fibres realigned themselves. This is evident in figures 6 and 7, which graphically represent the first cycle and fifth cycle means for the tubular knits[3]. The fifth cycle means indicate a lower load and, therefore, the effects of cyclic stretching and relaxing The most dramatic change in load can be observed in the first hour of testing, after which the load declines quite slowly.

On the other hand, Naturexx® exhibited the opposite behaviour (Figure 8). Although, load decay was observed over each individual cycle, the fifth cycle means indicate that the loop tension was increasing between cycles. The only possible explanation for this is the fact that Naturexx® was found to shrink slightly in the test (crosswise) direction with repeated washing between test cycles (Table 2). While gauge length remained the same on the Instron, extension was increasing slightly beyond 10% because of specimen shrinkage. It was also found that Naturexx® performs quite differently in several respects to the tubular knits. Load fluctuations occur throughout the 23 hour cycle with the general trend being one of decline.

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[3]Due to equipment malfunction, the mean for Tubigrip was determined utilizing the five cycles of specimen 3 and specimen 4.

Figure 6. Load Decay Over Time for Tubigrip
1st vs. 5th cycle means

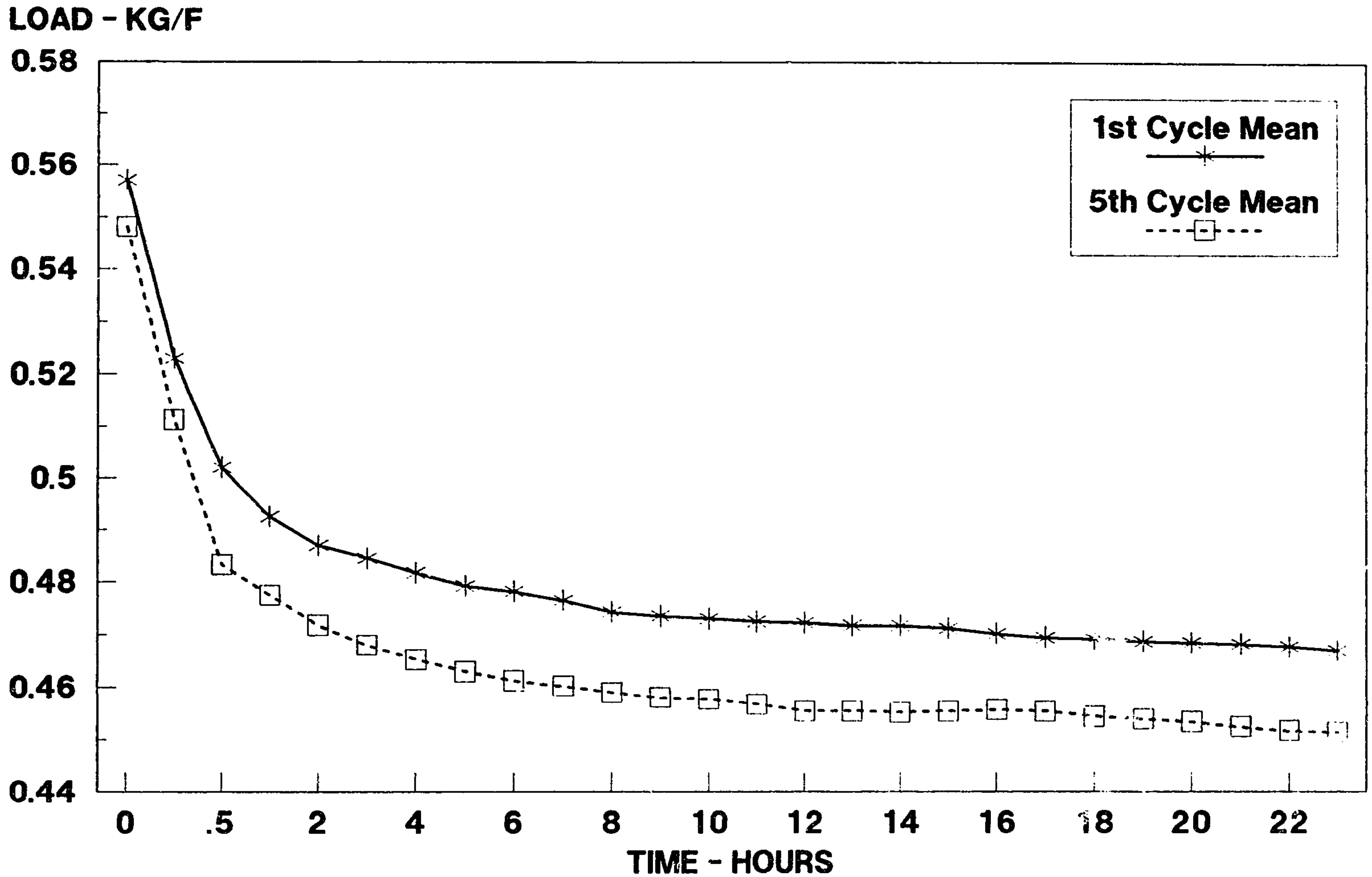

Figure 7. Load Decay Over Time for Raucopress
1st vs. 5th cycle means

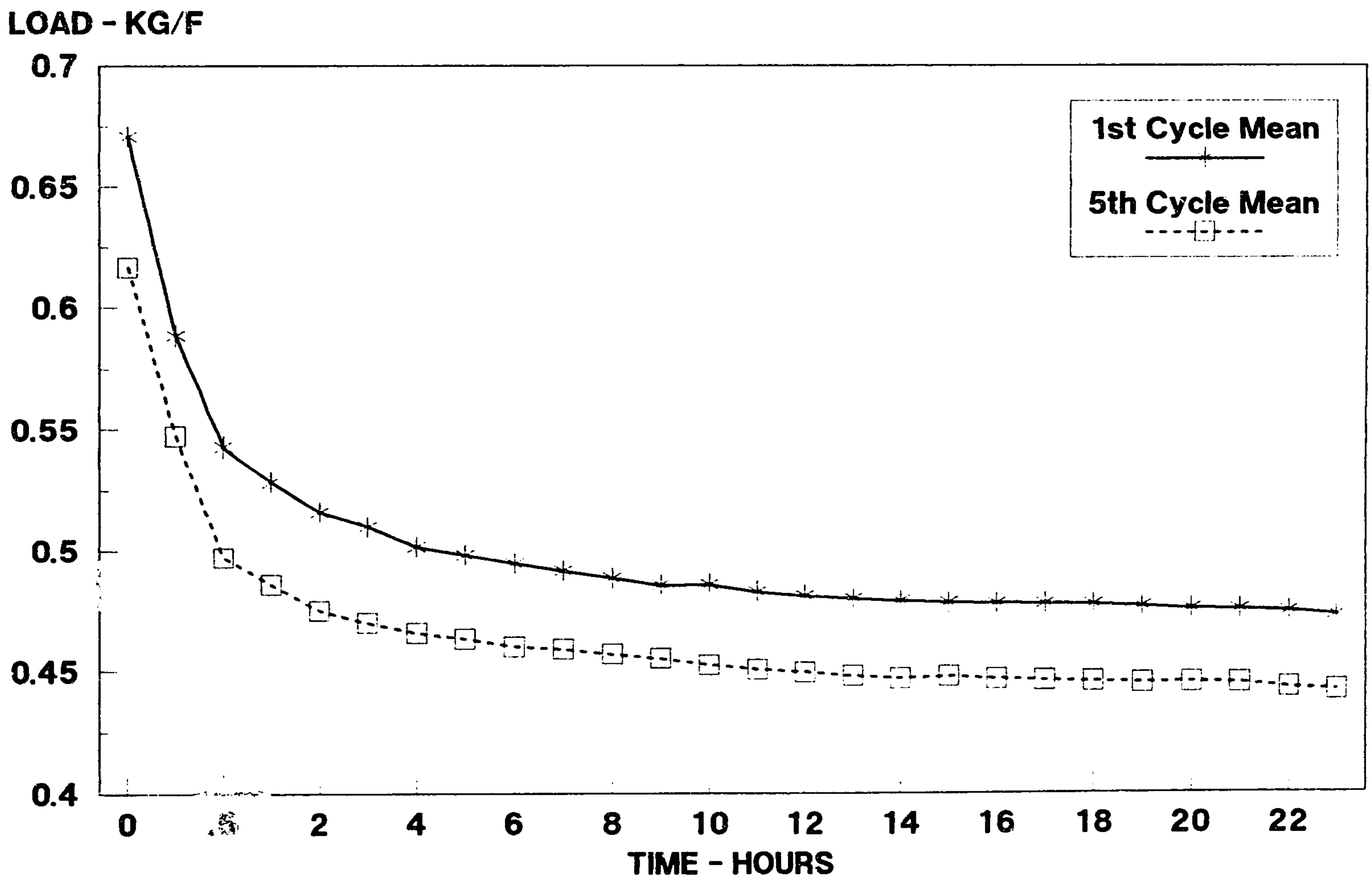

Figure 8. Load Decay Over Time for Naturexx
1st vs. 5th cycle means

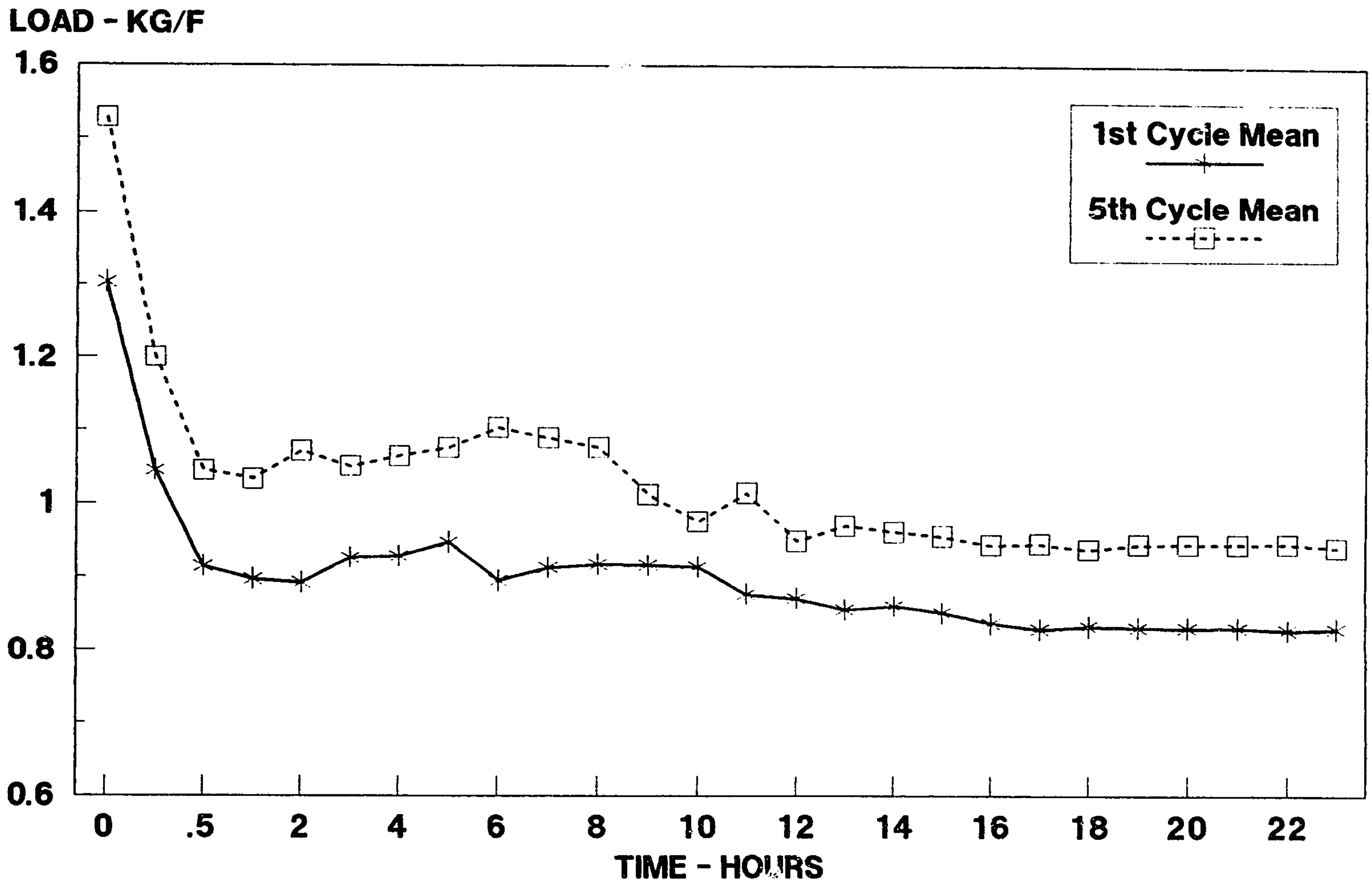

Table 2 indicates the dimensional change in control specimens and tension test specimens. Only one specimen for each fabric sample served as a control and each was marked in the same manner as the tension specimens. Control specimens of the tubular knit fabrics shrank in both directions during laundering, with more shrinkage occurring in the lengthwise direction. The Naturexx® control shrank only in the test direction. The tubular knit specimens tested for tension also shrank in both directions, and more so in the lengthwise. The lesser shrinkage in the crosswise direction of tension specimens could be attributed to permanent set (the specimens were permanently extended due to cyclic stretching). The difference in lengthwise shrinkage between control and test specimens is difficult to explain, but is possibly due to the method of marking the specimens using thread basting.

TABLE 2 DIMENSIONAL CHANGE[a] : CONTROL VS. TENSION SPECIMENS

FABRIC	Crosswise Shrinkage %	Lengthwise Shrinkage %
Control Specimen (n=1)		
Raucopress	3.10	5.00
Tubigrip	2.30	3.10
Naturexx	2.50	0.00
Tension Specimen Means (n=20)		
Raucopress	1.00	2.6
Tubigrip	1.70	3
Naturexx	1.40	0.30

[a] adapted from CAN/CGSB-4.2 58-M90 Colourfastness and Dimensional Change in Domestic Laundering of Textiles (CGSB,1990)

A comparison of the mean fifth cycles for the three fabrics can be found in Figure 9. Naturexx®, while at only 10% extension, exhibited the highest load and also experienced the greatest loss in load over time. Tubigrip® and Raucopress® behaved quite similarly in their average load decay over time. Raucopress® lost slightly more load over time than Tubigrip®.

Characterization

The second objective of the study was to determine relevant characteristics and specific performance properties of each fabric included in the study. This objective was met by testing the three fabrics following standard textile test methods or modified versions of these tests. The results are discussed in the following section.

Each of three fabrics included in the study was chosen as they were deemed suitable for use in constructing interim burnscar pressure garments. The three fabrics varied in their inherent properties A summary of the test results is found in Table 3.

Knitted fabric count was useful in determining the closeness of knit for each fabric. Naturexx® was found to have the highest density of 18.5 wales and 9.9 courses (yarns per centimetre); Tubigrip® had the lowest density of 12.3 wales and 9.1 courses (yarns per centimetre). Raucopress® fell in between in knitted fabric count at 13.9 wales/cm and 14.5 courses/cm. Tubigrip® was the thickest and Raucopress® the heaviest, with Naturexx® being both the thinnest and lightest.

Resistance of materials to water vapour diffusion was determined as it was considered important to the comfort of the wearer. When a fabric offers little resistance to water vapour diffusion, water vapour can easily pass through the fabric, yarns and/or fibres and diffuse to the environment cooling the wearer. Naturexx offers the least resistance to water vapour diffusion (with a value of 0.96 mm equivalent of still air). Raucopress® and Tubigrip® offer almost the same resistance (with values of 4.12 and 4.30 respectively) which are much higher than that of Naturexx®.

Figure 9. Load Decay Over Time: 5th cycle means

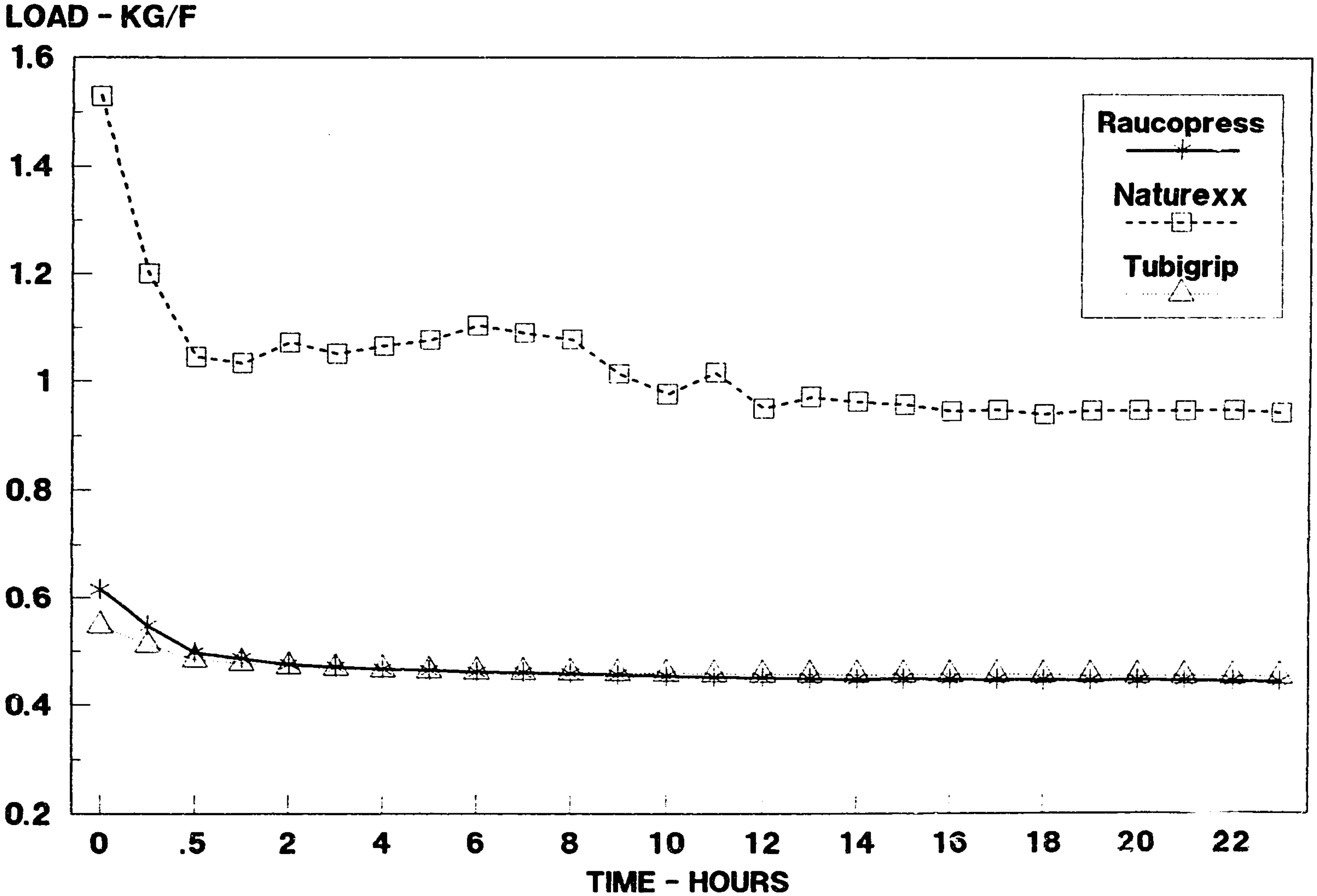

TABLE 3 <u>TEXTILE TESTING RESULTS</u>

Test Method	Raucopress	Tubigrip	Naturexx
Knitted Fabric Count[a] : n=5 average			
Wales/cm	13.9	12.3	18.5
Courses/cm	14.5	9.1	9.9
Fabric Thickness[b] (mm) n=5	1.29	1.40	0.74
Mass[c] (g/m²) n=5	354.2	340.7	328.7
Resistance of Materials to Water Vapour Diffusion[d] (mm equivalent of still air) n=4	4.12	4.30	0.96
Brush Pilling Test[e] Rating n=6	2	2	5
Air Permeability[f] Ave. air flow cm³/cm²·s⁻¹	51.3	53.2	57.7

[a] CAN/CGSB-4.2 No. 7-M88 Knitted Fabric Count - Wales and Courses per Centimetre
[b] CAN/CGSB-4.2 No. 37-M87 Fabric Thickness
[c] CAN/CGSB-4.2 No. 5.1-M90 Unit Mass of Fabrics
[d] CAN/CGSB-4.2 No. 49-M91 Resistance of Materials to Water Vapour Diffusion
[e] ASTM Designation-D 3511-82 Standard Test Method for the Pilling Resistance and Other Related Surface Changes of Textile Fabrics Brush Pilling Tester Method
[f] CAN/CGSB-4.2 No. 36-M89 Air Permeability

Overall, none of the fabrics tested offered an extremely high resistance to water vapour diffusion. For Naturexx®, this result was most likely due to the wicking properties of the fabric. Although wicking is more concerned with liquid water, the finish may have enhanced the diffusion of water vapour through the fabric. Darlington Fabrics, which manufactures Naturexx® did not indicate the specific type of finish, rather just that the fabric wicks moisture. As well, the fibres in the fabric do not absorb much moisture. This may have allowed the vapour to pass easily through the fabric structure as opposed to travelling through the fibres.

Results for the tubular knits are similar which is likely due to the similar fibre contents and construction of the fabrics . Both Tubigrip® and Raucopress® samples are composed of cotton with a cotton wrapped rubber insertion yarn every fourth row of the structure. Tubigrip's® slightly greater resistance to water vapour diffusion is likely due to it being a thicker fabric. However, the difference may not be significant.

Air permeability was determined for each of the fabrics included in the study. While all were quite permeable, Naturexx® had the greatest permeability (Table 3). These results can be considered in terms of the fabric properties previously discussed. Naturexx® was the thinnest of the samples under investigation. The fine, filament fibres in its tricot structure may also offer little resistance to air flow through the fabric. Tubigrip® may have a higher air permeability than Raucopress® because its knit structure is less compact than that of Raucopress®.

Specimens were given a numerical rating from 1 to 5 for pilling resistance and surface change. Tubigrip® and Raucopress® both received a rating of two as specimens pilled readily and severely. This is likely due to the knit structure and staple fibres used in the fabric. Pills can easily form on fabrics containing staple fibres in yarns because their ends can easily rise to the fabric surface. The yarns are not densely knit in either of these fabrics, allowing more yarns to be exposed to the test area and permitting fibres to pill. Naturexx® received a rating of five because no surface changes were apparent on the test specimens. Again, fibre length was responsible as nylon filaments were used in Naturexx®

and far fewer fibre ends can rise to the fabric surface (and pill). As well, the tricot knit is more compact than the tubular knits and helps to maintain the fibres within the fabric.

Pressure

The third objective of the study was to evaluate the pattern drafting system for garment pressure achieved. This objective was achieved using a specially developed pressure monitoring device and data from the second round of tension testing, in the following manner.

The pressure monitoring system provided useful information about the fabrics selected for the study. Their behaviour upon extension, relaxation and re-extension, indicated the effects of hysteresis present in each fabric. Hysteresis is a measure of energy loss which occurs between stretching and relaxing. When selecting a fabric for pressure garments, it is important to consider one with minimal hysteresis to provide the maximum power for minimal donning force. Both Raucopress® and Naturexx® experienced less hysteresis than Tubigrip®, making them a better choice for pressure garment design when this factor is considered.

The balloon membrane was found to contribute a large amount to the measured pressure during the testing. While this device gave pressure readings at higher tube extensions, minimum extensions were found to have negligible pressure values. The device was therefore not entirely suitable for measuring interim pressures of between 12 and 15 mm Hg, because it was somewhat insensitive to pressure in this range. The test was useful, however, in identifying a 'dead zone' in each fabric. This is a point at the beginning of balloon/garment expansion where the specimen did not exert any pressure. This dead zone varied for each fabric and requires further investigation.

The second part of the tension testing proved to be quite useful in determining tension reached by the fabrics at various extensions. This testing, done primarily to validate the pressure results, used three specimens of each fabric tested on the Instron.

The specimens were extended to a maximum point (100% for the tubular knits and 20% for the tricot knit) for one hour; the extension was then reduced systematically and the load was recorded after one minute at each extension. The mean load values were determined for each fabric and are listed in Table 4 and depicted in Figure 10.

The higher tension values obtained by Raucopress® over Tubigrip® are likely due to its greater number of elastic yarns per test specimen. It is also possible that 100% extension may be excessive for Tubigrip®, causing the elastic fibres to weaken and/or break. This should be further examined. Naturexx® also may have been extended too much as these test values do not readily compare to the results of the first round of tension testing. Likely, 60 seconds was not enough time for the load to stabilize and a longer period may produce more accurate results. Due to time constraints, however, these results were generalized as the behaviour of the fabric.

Figure 10 graphically represents mean tension versus percent extension for each fabric. Each fabric responds quite differently to extension as can be seen in the figure. This information was then utilized with La Place's Law to determine garment sizes appropriate for selected 'body' circumferences (for examples see Appendix 4). The radius of the body (from measuring) and the required pressure (mid-range pressure 13.5 mm Hg) are known. From La Place's Law ($P={}^{T}/_{R}$), the unknown tension can be obtained and once this has been determined, Figure 10 can be used to find the corresponding percent elongation. For example, a fabric tension of 20 N/M would correspond to 15 percent elongation for Naturexx®. Using this information we can calculate the initial size of the garment to be 0.0606 m, which would theoretically apply a pressure of 13.5 mm Hg to a body circumference of 0.0697 m (Appendix 4).

It therefore appears that La Place's Law can be used to determine interim burnscar pressure garment size based on "body" measurements and known fabric tensions at various extensions. Body measurements should be taken every 3.5 cm along the limb in order to achieve a proper fitting garment that applies the required pressure. Companies that produce custom garments produce measuring tapes that take measurements similar to this amount. The independent study, using the pressure monitoring device, showed

Figure 10. Tension at Various Extensions

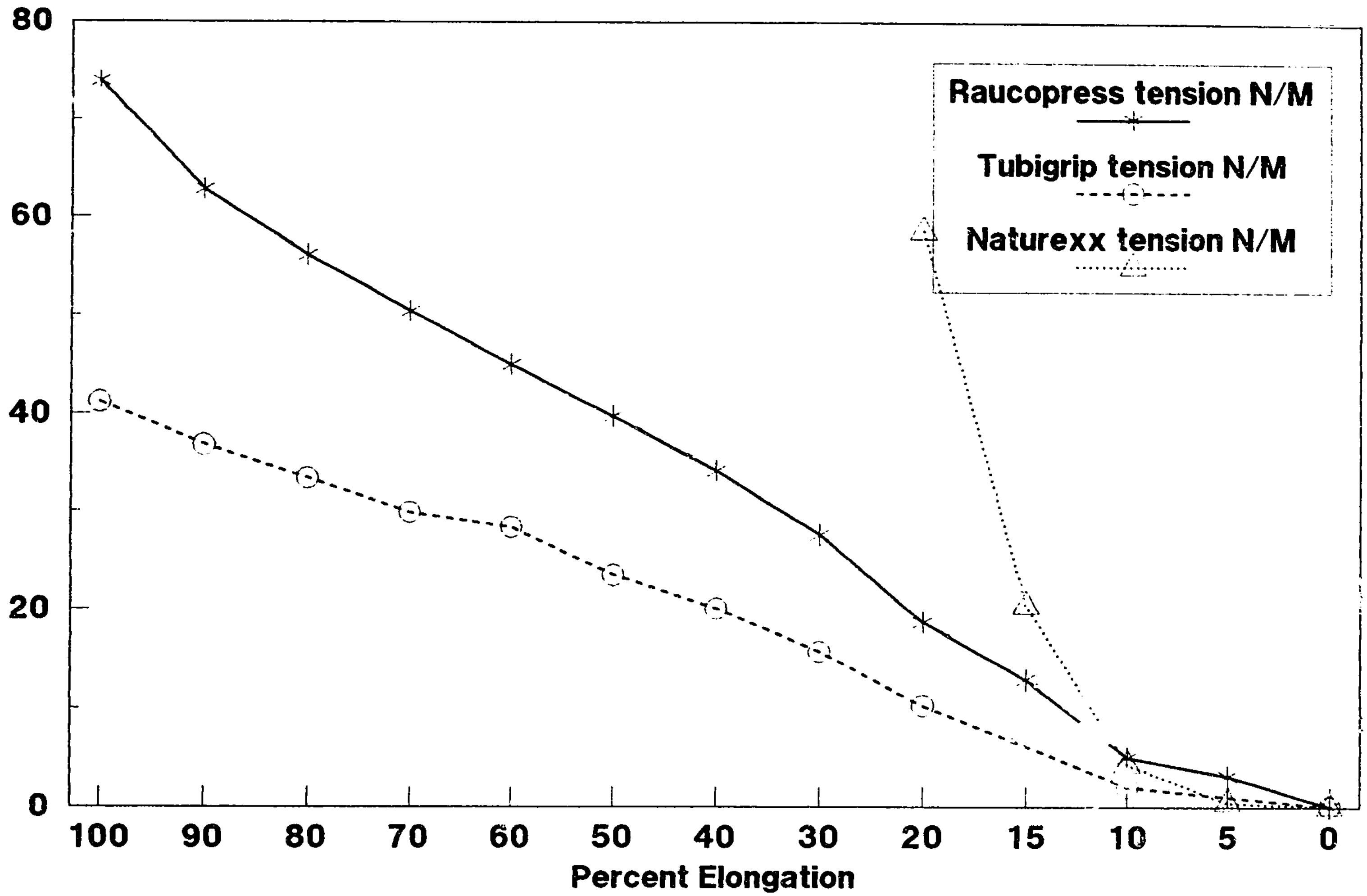

TABLE 4 MEAN TENSIONS AT VARIOUS EXTENSIONS

Extension %	Raucopress® tension N/M	Tubigrip® tension N/M	Naturexx® tension N/M
100	73.9	41.2	NA
90	[illegible]	36.8	NA
80	[illegible]	33.4	NA
70	50.4	29.9	NA
60	45	28.4	NA
50	39.8	23.5	NA
40	34.2	20.1	NA
30	27.6	15.7	NA
20	18.7	10.3	58.6
15	12.9	NA	20.4
10	5	2	4.3
5	3.1	NA	0.4

that predicted and measured pressure correlated well for Naturexx®. This should be explored further using a different membrane due to the balloon's large contribution to the overall pressure obtained. As well, this method of drafting patterns for interim burnscar pressure garments is only applicable to the limbs, which are more cylindrical in shape, due to the formula's primary use on cylinders.

From the calculations in Appendix 4, it was determined that as the radius of curvature of the "limb" changes, the appropriate percent elongation of the garment also changes. Some companies that produce customized pressure garments simply reduce circumference measurements by 10%. If La Place's Law holds true as suggested by the literature, a 10% reduction would only be appropriate for a small range of radii. Therefore, garments produced by using a standard percent reduction would not apply the required pressure to all areas equally.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to use the functional design process to develop a method of drafting customized interim burnscar pressure garments utilizing body circumference measurements and fabric properties. As part of this process, the pattern drafting method was evaluated for appropriate pressure application using a specially developed pressure monitor. Hypothetical body measurements were selected and used to determine garment size.

Interim burnscar pressure garments are used to treat patients with thermal injury once their burn wounds have closed and while they await the arrival of their long-term care pressure garments. Pressure garments have been highly successful in treating burnscars by reducing the severity and redness of the scar tissue involved. Interim treatment has consisted of treating the limbs with tubes of various circumferences or standardized garments, neither of which meet individual needs in terms of appropriate pressure application.

A functional design process is useful in designing clothing for special needs. The process allows for a thorough investigation of the design problem before garment design actually begins. A step-by-step approach allows the designer to work through the process and because the process is not linear, further investigation into areas already covered, is permitted and encouraged. Therefore, the designer, has control over which steps are most important to the design situation and can choose accordingly.

Three fabrics suitable for construction of interim burnscar pressure garments were included in the study. Naturexx®, Tubigrip® and Raucopress® were tested to determine their fabric structure, mass thickness, and performance attributes relating to comfort, tension, elastic recovery and dimensional stability. The properties varied among the fabrics tested. Each fabric was made up into "garments" that were tested on a pressure monitoring device to determine fabric characteristics upon stretching and relaxation and the pressures achieved by doing this. Further tension testing was conducted to determine the tension characteristics of each fabric at different levels of extension.

Each fabric behaved differently from the others when each test was considered. Naturexx® maintained a more consistent pressure on the pressure monitoring device compared to the tubular knits. While at minimum extension, it exerted a greater tension than did the tubular knits. It excelled in terms of air permeability and offered the least resistance to water vapour diffusion.

The tubular knit fabrics were quite similar in most aspects and the definitive test was found to be the use of the pressure monitoring system. Although this test was not as accurate in terms of monitoring pressures in the interim range, it provided useful information on the hysteresis effect of the fabrics. Tubigrip most readily lost energy between stretching and relaxing and therefore would not be as suitable as the other fabrics for interim pressure garments. This test was also useful in determining that the density of fabric on the body is quite important when determining pressure. The tubular knits could easily bunch up in places causing the elastic insertion yarns to come closer together, thereby increasing pressure in this area. While Naturexx® experienced fluctuations in load during each tension test cycle, it provided a more regular and consistent pressure when placed on the balloon device. This was likely due to the fact that it was less extensible than the tubular knits and, subsequently, pressure was more easily measured.

The objectives of the study were met through the textile testing and work with the pressure monitoring device. La Place's Law ($P = {}^{T}/_{R}$), was used to determine the garment size required to provide a pressure of 13.5 mm Hg. Tension values at various extensions were obtained from the second round of tension testing. The results of tensions versus elongation were graphed and utilized to determine garment size. "Body" measurements were chosen and once their radius (R) was determined , they were used in the formula. Pressure (P) was known to be 13.5 mm Hg and radius (R) was determined for the "body parts, therefore the corresponding tension (T) was easily calculated. From the graphed results of tension versus percent elongation, the tension just calculated could be found on the graph and the corresponding percent elongation required to give this tension determined for each fabric. This information (percent elongation) was used with the known body sizes to determine interim pressure garment size for each fabric.

Conclusions

The following conclusions can be drawn from the study:

1. La Place's Law can be utilized to determine appropriate garment sizes once fabric properties and body sizes are known. Simply reducing all body measurements by a standard amount (eg. 10%) does not apply the appropriate pressure to all areas of the body.

2. Knowing a fabric's properties when designing a garment using that fabric is essential. All fabrics behave differently during testing and their properties will affect their end-use behaviour .

3. The large load decay observed during the first hour of testing must be taken into account when designing pressure garments. As well, due to the large load decay in the first hour, pressure should not be monitored until after this period when the fabric stabilizes and provides a more consistent value.

4. Tension can be determined using the Instron Tensile Testing Machine. It is appropriate to use this equipment for tension testing over time when simple conversion factors to convert load values to tension are used.

5. There is still no accurate way of monitoring the pressure applied by a pressure garment.

Recommendations

From the textile tests conducted for this study, fabrics were characterized and pressures determined, and garment sizes were calculated using La Place's Law. Therapists can utilize whichever fabric they decide works best and suits their purposes. With the test data and through their own experience with fabrics, they can make an informed decision. The researcher feels that Naturexx® has some interesting qualities that may provide burn patients some comfort during recovery and pressure therapy. In addition to providing a more consistent pressure, air permeability and water vapour diffusion properties were found to be favourable. More research should be conducted to determine if these results are valid outside of a test environment.

Recommendations for future research on fabrics for interim burnscar pressure garments

The study was exploratory and the researcher recommends the following for future research:

1. Tension measurements over time at different levels of extension would be useful to determine as fabrics may apply constant pressure within a small range of extensions.
2. A useful tension test should include the force of donning held for a short period, then reduced to body size.
3. A further study should include determination of elastic yarn diameter as this may influence fabric tension and stress decay with cyclic stretching and relaxation.

4. Additional testing of cover factor and thermal properties may also prove useful in more fully characterizing fabrics. As well, testing for air permeability using stretched samples may better determine this property in an actual use situation.

Recommendations for future research of interim burnscar garments:

1. Research still needs to be conducted on a suitable pressure monitoring device that would give accurate readings over a range of body dimensions while not interfering with or distorting circumference measurements.
2. Wear trials of garments made of the different fabrics would be useful in choosing one fabric over the others for interim pressure garments.
3. A comparison of quantitative data from textile testing and qualitative data from wear trials would also be useful when choosing a fabric for pressure garments.

Recommendations for Occupational Therapists:

1. Research needs to be conducted on the pressure applied by pressure garments on soft tissue areas of the body. Occupational therapists need to be aware of the pressures actually applied by the garments they use to treat thermal injury.
2. The findings of this study may be useful to occupational therapists when treating the limbs or places on the body more cylindrical in shape, as La Place's Law holds true for a perfect cylinder. For such areas, use of La Place's Law and fabric tension measurements should facilitate the achievement of appropriate pressures in the application of pressure garments.
3. Tubular knits tend to bunch in places and this increases pressure in that area. Occupational therapists need to indicate to their clients the number of elastic yarns per centimetre when the tubular knits worn.

Recommendations for Textile Manufacturers:

1. Manufacturers of elastic fabrics need to work on developing a fabric which maintains its load over time. Experimentation with elastic yarns, texturizing, and structure could lead to improvement of this property.
2. Because the tubular knits tend to bunch in places, subsequently increasing pressure in this area, manufacturers need to indicate to consumers and occupational therapists, the way in which the tubes are to be worn (number of elastic yarns per centimetre).

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APPENDIX 1

Consent form and Information Sheet

for Focus Group Interview

CONSENT FORM

TITLE OF THE PROJECT: "Subjective Analysis of Interim Burnscar Pressure Garments"

INVESTIGATOR: Laurie Boone

INFORMATION SHEET

The purpose of this focus group interview is to collect subjective opinions about the interim burnscar pressure garments or bandages that you were treated with after your burn wounds closed and before you received your customized long-term garments. Information gathered from this interview will be used to develop a new interim pressure garment pattern drafting system that takes into account fabric properties, pattern design, and wearer comfort. You will be required to either write down answers or think about a few questions that I will ask. Then, in a group setting, you will have the opportunity to discuss your feelings about those questions. The amount of time required for you to commit to this project will be dependent on the amount of discussion generated. I estimate that you should set aside a half to a full hour of your time.

CONSENT

I acknowledge that the research procedures described on the Information Sheet (previous page) and of which I have a copy have been explained to me, and that any questions that I have asked have been answered to my satisfaction. In addition, I know that I may contact the person designated on this form, if I have further questions now or in the future. I have been informed of the alternative to participation in this study. I understand the possible benefits of joining the research study, as well as the possible risks and discomforts. I have been assured that personal records relating to this study will be kept confidential. I understand that I am free to withdraw from the study at any time without jeopardy to myself.

The person who may be contacted about this research is:
Laurie Boone
Telephone #439-7649

____
(Name)

____
(Signature of Participant)

____
(Name)

____
(Signature of Witness)

____
(Date)

____
(Signature of Investigator)

APPENDIX 2

Focus Group Interview Guide

FOCUS GROUP INTERVIEW
ON INTERIM PRESSURE GARMENTS

Group: ___ Date: ___
Location: _______

A. Instruct participants to sit in a group (for ease of recording responses).

B. We are going to focus on the interim pressure garments that you wore before you received your commercially made custom pressure garments. I am interested in your like and dislikes regarding the garments or bandages that you wore. I will ask you some questions that I would like you to individually write down your responses to. Then, you will have an opportunity to discuss these with the rest of the group.

1. Think back to the first interim pressure garment or bandage that you were treated with after your wounds closed. Common forms of treatment are either a commercially made interim pressure garment (cotton knit), a tubular knit (exhibit 1) such as those produced by Tubigrip or Jobst or a custom-made interim garment made by a technician. What type of garments were each of you treated with initially?

(Break up respondents into groups according to type of treatment, indicate number in each group)

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

**IF PARTICIPANTS IN FOCUS GROUP ARE MISSING DIGITS, YOU MIGHT NOT BE ABLE TO ASK THEM TO WRITE DOWN THEIR FEELINGS. INSTEAD, HAVE THEM THINK ABOUT EACH QUESTION.

2. Please write down (or think about) at least three things that you felt were good regarding the garment or pressure support. What was good about it?

(PAUSE)

3. Please write down (or think about) at least three things that you felt were not good about it.

(PAUSE)

C. Now, in turn I would like you to tell me what each of you has written (or your thoughts).

i). Good things about the interim pressure treatment.

GROUP A = COMMERCIAL **GROUP B = TUBULAR KNIT** **GROUP C = CUSTOM**

ii). Things about the interim pressure garment that were not good.

GROUP A = COMMERCIAL **GROUP B = TUBULAR KNIT** **GROUP C = CUSTOM**

D. Discussion

1. (Address Group A) For those of you wearing the commercially made interim garments, was it necessary to have them altered to achieve a better fit?

____

____

____

____

____

I'd like you to tell me more about this. Were numerous alterations needed or were just a few required?

2. (Address Group B) For those treated with a tubular knit, were alterations necessary to achieve a better fit?

____

____

____

____

____

Was it necessary to wear more than one tubular bandage at a time (layered)?

3. (Address Group C) Were there many alterations necessary with the custom garments constructed by the technician?

____

____

____

____

____

4. One thing many of you seemed to mention was:

____.

Do any others agree that this is important?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

5. An other thing many of you mentioned was:

____.

I'd like you to tell me more about this. Why is this concept important to you?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

6. Many of you seemed dissatisfied with:

____.

I'd like you to tell me more about this. Why is this important to you?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

7. No one seemed to mention the durability of the garments to washing. Did you find that the garments stood up to washing for the required term of treatment?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

8. How did the garments feel next to the skin? Were they soft or rough? Did they cause itchiness?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

9. Did you find the garments to be too warm while wearing them?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

10. Did the garments remain in their correct position while wearing them?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

11. Did any of the garments lose their shape before interim treatment ended? Was it necessary to have the garment or tubular knit altered because it lost its shape? Was it necessary to acquire another garment due to the initial one loosing shape or not applying pressure?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

12. Was the pressure applied by the garment or bandage adequate? Too much (cut off circulation)? Too little (loose and slipping)?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

13. Were the interim garments or bandages worm continually?

GROUP A = COMMERCIAL GROUP B = TUBULAR KNIT GROUP C = CUSTOM

If not, why not?

____

14. I'd like to know when each of you was injured and in what area were you burned?

subject 1	treatment =	date =	area =
subject 2	treatment =	date =	area =
subject 3	treatment =	date =	area =
subject 4	treatment =	date =	area =

APPENDIX 3

Pressure Monitoring System

An Evaluation of the Pressure Exerted by Interim Pressure Garments in the Treatment of Thermal Injury*

The project studied three different fabrics (Tubigrip®, Raucopress®, and Naturexx®), that could be utilized to construct pressure garments for burn patients. A special apparatus was developed to monitor pressures applied by the fabrics under investigation at various extensions. This independent project was completed by Capjack (1994), in Mechanical Engineering at The University of Alberta.

Three specimens of varying diameters were tested on the pressure monitoring device. The tubes were slipped over the balloon membrane, which was then inflated for a one hour period. Calipers were used to determine the diameter of the tube and balloon. Air was then let out, calipers were again used to measure diameter, and pressure was recorded.

These pressure tests showed that each fabric experienced hysteresis, indicating some uncertainty in the results. The tubular knits were found to have the largest variation in pressure due to hysteresis, with Tubigrip® having more than Raucopress®. Naturexx® showed minimal pressure change due to hysteresis.

The device was also utilized to develop a graph of pressure versus diameter of the balloon at extension. Since the initial diameter of the tube before extension was also known, the extension of the fabric giving the appropriate pressure could be determined. Pressure and diameter were measured after the balloon and garment were expanded and held at their maximum point for one hour to avoid the energy loss between stretching and relaxation. Measurements were then recorded as the balloon was reduced in size. These measurements were used to express fabric behaviour in graph form.

* Author's summary of Capjack, G. (1994). An Evaluation of the Pressure Exerted by Interim Pressure Garments in the Treatment of Thermal Injury. Unpublished manuscript, University of Alberta, Mechanical Engineering, Edmonton.

Each fabric appeared to have a "dead zone", which was an area on the graph where pressure and tension did not appear to increase until the fabric was stretched to a certain percentage. This needs to be further investigated using different initial extensions. As the tubes were expanded to their maximum point and held for one hour, it is likely that the elastic components in the fabrics broke and decayed during this period. This does not accurately represent real life wearing conditions. A garment would be overstretched during the brief period of donning and then conform to fit the body and apply pressure. For the purposes of gaining data on fabric behaviour, the pressure monitoring system was useful.

The balloon membrane used in the monitoring device indicated that it contributed a large amount to the overall pressure obtained by the balloon and fabric tube combination, especially for the tubular knits. Therefore, the tubes showed minimal impact on the pressures achieved. To more accurately obtain data on fabric pressure application, the use of a different membrane should be explored.

APPENDIX 4

Interim Garment Size Calculations

Interim Pressure Garment Calculations

La Place's Law ($P = {}^{T}/_{R}$)

P= pressure
T= tension
R= radius (body)

Example

Body circumference = 0.0697 m

Body radius = C÷2∏

r = 0.0111 m

$T = {}^{PR}/_{7.5 exp -3}$ *7.5 exp -3 conversion factor from pascals to mm Hg

P = 13.5 mm Hg

R = 0.0111 m

T = 20 N/M (see Figure 11 to determine % elongation for Naturexx®)

From Figure 11, Naturexx® has an elongation of 15% at a tension of 20 N/M)

To determine garment size

Take body circumference ÷ 1.15 (this gives you a reduction of 15%)

0.0697 m ÷ 1.15 = 0.0606 m

"Body" Circumference M	Radius M	Tension (N/M)	Raucopress		Tubigrip		Naturexx	
			% Ext.	Gar. Cir.	% Ext.	Gar. Cir.	% Ext.	Gar. Cir.
0.145	0.0231	41.5	52.5	0.1	100	0.07	17.5	0.12
0.12	0.0191	34.4	39.5	0.09	82	0.07	16.5	0.1
0.1	0.0159	28.6	30	0.08	58	0.06	16	0.09