DEVELOPMENT OF PROTECTIVE CLOTHING FOR FIRE FIGHTERS

A PROJECT REPORT

Submitted by

V.CHINNASAMY (0810203302)
S.KALIMUTHU (0810203308)
M.VIGNESH (0810203324)

In partial fulfillment for the award of the degree

of

TEXTILE TECHNOLOGY (FASHION TECHNOLOGY)

in

TEXTILE TECHNOLOGY (FASHION TECHNOLOGY)

KUMARAGURU COLLEGE OF TECHNOLOGY

(An Autonomous Institution affiliated to Anna University of Technology, Coimbatore)

APRIL 2012

KUMARAGURU COLLEGE OF TECHNOLOGY

(An Autonomous Institution affiliated to Anna University of Technology, Coimbatore)

BONAFIDE CERTIFICATE

Certified that this project report "**DEVELOPMENT OF PROTECTIVE CLOTHING FOR FIRE FIGHTERS" is the bonafide work of**

V.CHINNASAMY (0810203302)

S.KALIMUTHU (0810203308)

M.VIGNESH (0810203324)

Who carried out the project work under my Supervision.

SIGNATURE

DR.J.SRINIVASAN
HEAD OF THE DEPARTMENT

Department of Fashion Technology

Kumaraguru College of Technology

Coimbatore-641049

SIGNATURE

DR.R.SHANTHI
ASSISTANT PROFESSOR(SRG)

Department of Fashion Technology

Kumaraguru College of Technology

Coimbatore-641049

Certified that the candidates with the University Register No. **0810203302, 0810203308, 0810203324** were examined by us in the project viva-vice examination held on 12.4.12...

12.4.12
INTERNAL EXAMINER

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

First and foremost we, thank the "God Almighty" for endowing us with his immense blessings which helped to overcome the hurdles, paving way for successful completion of the study.

We express our deep gratitude to our respected Co-Chairman Dr.B.K.Krishnaraj Vanavarayar and our sincere gratitude to our Director Dr.J.Shanmugam and our Principal Dr.S.Ramchandaran for their support and for proving the required facilities for carrying out this study.

We also express our gratefulness to Dr.J.Srinivasan, Professor and Head of the Department of Fashion Technology, Kumaraguru College of Technology for extending his timely help and encouragement throughout the project.

We wish to thank our project co-coordinator and guide Dr.R.Shanthi Asst.Professor (Sr.Grade) Department of Fashion Technology, Kumaraguru College of Technology for his valuable help, guidance, assistance and encouragement throughout the study.

We express our sincere thanks to Prof.V.Sankaran, Coordinator and Mr.Gopinath, Senior Scientific Officer, KCT TIFAC CORE and Mr.VaradaRajan, for their immense support and facilitating to carry our project at TIFAC.

We express our deepest sense of gratitude to Lab technicians of SITRA –Chemistry Department for their valuable help, guidance for the project.

Last but not the least our heartfelt gratitude to Department of Textile Technology, Kumaraguru College of Technology. Our beloved parents and friends for extending the support, which helped us to overcome obstacles of the study.

TABLE OF CONTENTS

CHAPTER NO	TITLE NO	PAGE NO
	ABSTRACT	5
	List of tables	
	List of figures	
1.	INTRODUCTION	8
2.	REVIEW OF LITERATURE	13
	2.1 Flame retardant fibers	
	2.2 Importance of Cotton, Viscose and Bamboo fibers	14
	2.3 Yarn Development	
	2.4 Fabric Development	15
	2.5 Fire Fighters clothing standards	16
	2.6 Comparison between Chemical Finish & Fibers	
3.	METHODOLOGY	17
	3.1 Survey	
	3.1.1Selection of area	
	3.1.2Selection of sample	18
	3.1.3Selection of tool	
	3.1.4Collection and consolidation of data	
	3.2 Experiment	19
	3.2.1 Selection of fiber	20
	3.2.2 Blend Ratio	
	3.2.3 Development of yarn	21
	3.2.4Development of fabric	22
	3.2.5Testing of yarn and fabric	23
	3.3 Statistical Analysis	37
	3.4Development of protective clothing	43
4.	RESULTS AND DISCUSSION	44
5.	CONCLUSION	51
6.	REFERENCE	54
7.	APPENDIX	55

ABSTRACT

Protective clothing is of great importance to fire fighters. Protective clothing for fire fighters is designed to perform several functions of which protection from heat and flame is one of the most important. Today's fire fighter protective clothing designs are based on years of field experience and research studies, which addressed structural fires. Much of the work is concentrated on the fire environment where a fire fighter has to face and withstand heat and flame hazards. Lack of protective clothing results in burn injuries and skin problems. A survey was conducted in fire service stations around Coimbatore, to analyze the existing clothing characteristics and it was found that 99% of the people surveyed were using normal clothing without any protection against fire hazards. A great deal of research has been done to develop protective clothing with advanced fibres like Trevira and Basofil. Textiles made from Trevira fibers and yarns are permanently flame retardant. Unlike fabrics that receive a surface treatment at a later stage. Trevira textiles offer long-term security against fire since the chemical structure of Trevira is slightly different from polyester fibre whereby – a phosphor-organic compound is firmly anchored in the fibre, imparting flame retardant properties, which are not affected by external influences. Hence an attempt was made to develop protective clothing for fire fighters using flame retardant fibre Trevira in combination with Cotton, Viscose and Bamboo. A 50/50 blend ratio was selected to cover the comfort aspects of the protective clothing. The fabric developed from 100% Trevira and its blends was tested for physical, mechanical, comfort and flame retardant properties. The results indicated that 100% Trevira exhibited the best flame retardant property along with basic comfort. The end product was developed based on the suggestions given by the respondents gathered through the survey. Chemical finishes which impart fire retardancy need water, energy and effluent treatment during processing moreover the finish wears down with usage and may cause skin problems. This study uses flame retardant fiber and thereby minimizes the usage of natural resources as well as produces effective protective clothing for fire fighters.

Table No	List of Tables	Page No
1.	Nomenclature of the samples	20
2.	Yarn development process	21
3.	Details of hazards faced during fire fighting	44
4.	Existing clothing characteristics	45
5.	Checking association between the characteristics	45
6.	Physical properties of Trevira and its blends	46
7.	Mechanical properties of Trevira and its blends	48
8.	Comfort properties of Trevira and its blends	50

Figure no	List of figures	Page no
1.	Fire Fighters working Condition	10
2.	Development of fabric	22
3.	Yarn Appearance tester with Black Board	27
4.	Pilling tester	30
5.	Inclined flammability tester	31
6.	Stiffness tester	32
7.	Air permeability tester	33
8.	Water vapor permeability tester	34
9.	Thermal resistance tester	35
10.	Spray rating tester	36
11.	Design of the protective wear	43

INTRODUCTION

1. INTRODUCTION

The importance of protective clothing is to keep body safe from hazardous materials and harm. Additionally, there are various kinds of clothing that are designed to provide even more kinds of protection. However simply the understanding that the unsafe clothing may not only fail to protect you properly but may actually be considered a hazard in some circumstances and situations. Public servants such as police and fire personnel require protective clothing such as bulletproof vests and fireproof suits in the routine fulfillment of their commitment to protect the public and uphold the law. Their clothing works not only to save their lives but the lives of others such as hostages and those who are trapped in burning buildings. Protective clothing or other garment or equipment designed to protect the wearer's body from injury by blunt impacts, electrical hazards, heat, chemicals , and infection, for job-related occupational safety and health purposes, and in sports, martial arts, combat, etc. The terms "protective gear" and "protective clothing" are in many cases interchangeable; "protective clothing" is applied to traditional categories of clothing, and "gear" is a more general term and preferably means uniquely protective categories, such as pads, guards, shields, masks, etc. Items such as fire extinguishers, first aid kits are equipment to support the personal protection of the subject.

The use of personal protective equipment is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels. Chemical suits are designed to protect the entire body from exposure to harmful and possibly fatal chemicals. Without these suits, it would be impossible to contain dangerous chemical spills or explosions where nuclear waste or other potentially fatal chemicals must be cleared away and disposed of properly. These suits protect the wearer so that clean up is done without risk. Some forms of protective clothing are available in a disposable variety. The dual function of this type of clothing is that it not only provides protection but can be discarded after use. The durable materials used to make this type of clothing are breathable but non-porous, ensuring safe covering during use. Such materials are also being made with earth-friendly products so that disposable does not produce subsequent hazard.

Temperature sensitive clothing works well for those who fight extreme temperatures, both hot and cold. This is of critical importance since too much of either temperature can be hazardous and eventually fatal

Temperature sensitive clothing works well for those who fight extreme temperatures, both hot and cold. This is of critical importance since too much of either temperature can be hazardous and eventually fatal to the body that is not properly protected from too much heat.Protective clothing has various types of fasteners, buckles, zippers and closures that are a part of the clothing. The protective nature of this clothing works only when closures are put together in the right manner. Containment is one of the major factors at work for protective clothing and the only way to contain the person safely inside the clothing is to ensure that directions are followed regarding how to close and wear every piece.

Importance of protective clothing:

Protective Clothing is of immense importance and is currently observed in many work related environments these days. There are certain professions that involve the placement of a person's life at risk. A large degree of such risk can be mitigated or covered by mandating him/her to don on protective clothing instead of their personal clothes. Protective clothing does not use the conventional fabrics that are used for creating our every day wear. High quality fabrics are instead incorporated in their creation as they tend to be resistant to certain effects and materials that they are exposed to. Just wearing these clothes are enough to provide a reasonable amount of fortification against substances that may otherwise have been fatal.The importance of clothes that act as safeguards cannot be underestimated as they play a noteworthy role in saving lives. The following points help get a clearer understanding of the actual significance of this type of clothing:

People who are engaged in the maintenance of law and order benefit highly by bulletproof vests and clothes as they come in contact with criminals on a frequent basis and may have to face shoot outs and stabbings when such situations arise. Protective clothing such as this helps them do their job better as they can plunge into the field of battle fearlessly and come out unscathed. People who work with chemicals in the pharmaceutical industry or for research purposes come in contact with highly toxic chemicals some of which have the ability to cause serious burns or even death when they come directly in contact with a person's skin or digestive system. For this purpose, it is crucial for people working in this field to wear protective clothing while going about their daily business. There are thick, powerful and durable fabrics that are used to manufacture such clothes and they act as an intermediate layer that does not allow the chemicals to come in contact with the skin by any chance. However, you must make sure before wearing them that there is absolutely no wear and tear or holes of any kind that may have occurred over time as this will mean risking your life. There are multiple zippers and buttons that such

The job profile of fire fighters requires them to face death every day as they conduct rescue operations and try to douse flames. There may be instances when they may have to enter a completely inflamed building in order to perform a rescue operation. They may have to literally pass through an inferno in order to successfully do so. They thus have special fire proof vests and protective clothing that helps protect them when they perform such hazardous missions. Their skin remains protected from harmful burns and they can go about their tasks unhindered. Astronauts who go into space to probe into the mysteries of the universe cannot do so in their regular clothing. They also don protective clothing by way of space suits that are made of materials that can withstand immense heat and immense cold. They contain the person inside and create a special temperature and atmosphere that is suitable for the human body.It can thus be said that the professions that come with high perils usually make it absolutely vital for the people to wear such clothing. All safety procedures regarding their wear must be followed to the slightest degree in order to protect oneself.

Figure 1- Fire Fighters working condition

Fire Suits

Fire suits like safety fire suits, fire entry suits, fire proximity suit and kevlar fire suits, nomex fire suits that is widely used by the fire fighting servicemen who takes active part in fire extinguishing process. These suits are specially designed in order to give complete safety from the heat and other factors. Nomex fire suits, fire proximity suit and fire entry suits in various sizes and ensured of complete safety in any fire condition. The fire suits can also be customized as per the specifications provided by the clients.

Fire proximity suit:

A **fire proximity suit** (also, **silvers** or **silver bunker suit**) is a suit designed to protect a firefighter from high temperatures, especially near fires of extreme temperature such as aircraft fires.Fire proximity suits first appeared during the 1930s, and were originally made of asbestos fabric (hence also known as the **asbestos suit**). Today they are manufactured from vacuum-deposited aluminized materials that reflect the high radiant loads produced by the fire.There are three basic types of these aluminized suits namely Approach suit—used for work in the general area of high temperatures such as steel mills and smelting facilities. (Ambient heat protection up to ~200 °F (93 °C).); Proximity suit—used for aircraft rescue and fire fighting (AR-FF) and, in more heavily insulated versions, for kiln work requiring entry into the heated kiln. (Kiln suit ambient protection ~2,000 °F (1,093 °C) and proximity ambient protection~ 500 °F (260 °C)) and Entry suit—used for entry into extreme heat and situations requiring protection from total flame engulfment. Most commonly made of Zetex or Vermiculite and not aluminized. (Entry suit ambient protection ~2,000 °F (1,093 °C)) for short duration and prolonged radiant heat up to 1,500 °F (816 °C).

The fire fighters of the country and the states do not use any specialized clothing as uniforms for fire fighting. Except for a few cases, they use normal clothing and there is a need to develop protective wear for them. Many chemical finishes have been used for this function and the investigators felt the requirement to develop safety wear for this hazardous job. Hence this study was undertaken with the following objectives:

Objective:

- To collect data about requirements of clothing for fire fighters in and around Coimbatore.
- Fiber blending and Yarn development.
- Development of fabric with improved performance properties.
- Testing of Yarn and Fabric (physical, mechanical, comfort, flame retardant properties)
- Design and development of Protective wear.

Scope of the project:

Protective clothing plays a vital role to protect firefighters from hazards. The fibers used for the development have inbuilt safety aspects to stand firm against flame, and this eliminates chemical finishes to be imparted on the fabric. Chemical finishes may lead to problems like skin diseases and health problems, chemical finishing treatment include chemicals, effluent, that may turn hazardous to the environment. Development of fabric from fire retardant fibers absolutely eliminates entire chemical finishing process.

Clothing developed by flame retardant fibers are eco friendly and provides good comfort properties than chemically finished fabrics.

Since there is a growing demand for clothing made from flame retardant fibers, they can also be used for other commercial applications.

Need for protective clothing for fire fighters is extended from day –to-day to protect themselves from diverse series of accidents. This conditions demand for quality and design alteration of the product.

Therefore innovative thinking is needed in the development protective clothing to meet customer desires quality standards.

LITERATURE REVIEW

2. REVIEW OF LITERATURE

The review of literature was studied under the following headings

2.1 Flame retardant fibers

2.2 Importance of Cotton, Viscose and Bamboo fibers

2.3 Yarn Development

2.4 Fabric Development

2.5 Fire Fighters clothing standards

2.6 Comparison between Chemical Finish & Fibers

2.1 Flame retardant fibers

Textiles made from the fibers (built in safety) are permanently flame retardant. Fire-retardant fibers have lasting functioning for retard fire spread. The fiber can produce non-toxicity gas to retard fire spread when catch fire.

Nomex fiber has excellent fire resistant property commonly used to produce protective clothing. Blending of nomex fiber with cotton reduces cost and improves comfortability of the fabric. For more than thirty years, Kermel® fiber has had tremendous success in providing innovative solutions for firefighter clothing. The non-flammable fiber has a very high resistance to abrasion, a thermal conductivity. It also has an excellent resistance to chemicals. Kevlar® aramid fiber is used to make a variety of clothing, accessories, and equipment safe and cut resistant. It's lightweight and extraordinarily strong, with five times the strength of steel on an equal-weight basis. Permanently flame-resistant polyester fibers, such as Trevira are not treated with a surface flame-resistant chemical but rather the flame-resistant properties are permanently built into the molecular chain of the fiber and cannot be removed.

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs.html

http://www.kermel.com/site/Production-of-High-Tech-non-flammables-Fibres-640.html

http://www2.dupont.com/personal-protection/en-us/dpt/kevlar.html

2.2 Importance of Cotton, Viscose and Bamboo fibers

Cotton has many characteristics that help to account for its comfort. The simplest characteristic is its soft hand, meaning its soft feeling to the skin. Cotton is also good in hot weather because it is a natural fiber that allows for good ventilation. Cotton is also good in humid weather because of the way the cellulose is arranged in each fiber. "Each fiber is made up of twenty to thirty layers of cellulose coiled in a neat series of natural springs"; this arrangement allows cotton the ability to absorb moisture. http://cotton.missouri.edu/Classroom-Comfort.html

Bamboo fiber is a regenerated cellulosic fibre produced from bamboo. Starchy pulp is produced from bamboo stems and leaves through a process of alkaline hydrolysis and multi-phase bleaching. Produce bamboo fibre has a strong durability, stability and tenacity. Bamboo fabric is made of 100% bamboo pulp fibre. It is characterized by its good flame resistance property, hygroscopicity, excellent permeability, soft feel, easiness to straighten and dye and splendid color effect of pigmentation.

http://www.fibre2fashion.com/industry-article/textile-industry-articles/properties-of-bamboo-fibre/properties-of-bamboo-fibre1.asp

Viscose is a regenerated cellulosic fiber has many characteristics, the properties varying according to the method of processing. viscose can be dyed and printed extremely well and exhibit exceptionally brilliant colours. Viscose breathes actively, regulates high moisture absorption. temperature well, making it especially pleasant to the skin.

2.3 Yarn Development

Ring spinning is a method of spinning fibres, such as cotton, flax or wool, to make a yarn. The ring frame developed from the throstle frame. Ring spinning is a continuous process, unlike mule spinning which uses an intermittent action. In ring spinning, the roving is first attenuated by using drawing rollers, then spun and wound around a rotating spindle which in its turn is contained within an independently rotating ring flyer.

Traditionally ring frames could only be used for the coarser counts- but they could be attended by semi-skilled labor.

"Textile spinning –Importance of spinning for cotton by Dr. Noor Ahmed Memon"

http://en.wikipedia.org/wiki/Ring_spinning

2.4 Fabric Development

Weaving is a method of fabric production in which two distinct sets of yarns or threads are interlaced at right angles to form a fabric or cloth. The other methods are knitting, lace making. The longitudinal threads are called the warp and the lateral threads are the weft or filling. The method in which these threads are inter woven affects the characteristics of the cloth. Cloth is usually woven on a loom, a device that holds the warp threads in place while filling threads are woven through them. A fabric band which meets this definition of cloth (warp threads with a weft thread winding between) can also be made using other methods, including tablet weaving, back-strap, or other techniques without looms.

Twill weave:

Twill is a type of textile weave with a pattern of diagonal parallel ribs (in contrast with a satin and plain weave). This is done by passing the weft thread over one or more warp threads and then under two or more warp threads and so on, with a "step" or offset between rows to create the characteristic diagonal pattern.

http://en.wikipedia.org/wiki/Weaving

2.5 Fire Fighters clothing ,standards, design:

Fire fighters clothing to be designed accordingly to meet the specifications and needs of the fire fighter when they exposed to flame.

Fire fighters clothing has to satisfy general requirements like

Thermal protection

Convenience during interventions

Comfort under normal conditions

Proper ventilation system performed due to release of heat produced by natural fire fighters metabolism.

Construction and design of the protective clothing for fire fighters:

Special attention should be given to the construction of certain parts of garment that will protect the user as to prevent penetration of moisture or chemicals under the garment

•very important is to determine the comfort of the garment which multi layered way of dressing have to satisfy, while not inhibit movement in extreme conditions

"Design and construction of functional protective clothing for firefighters-Slavica Bogovic,„Anica Hursa Šajatovic"

2.6 Comparison between Chemical Finish & Fibers

Finishes typically reduce the main effect of a finish type, for example the flame retardant effect is decreased by nearly all other types of chemical finishes as they add flammable components to the fabric.

Fortunately true antagonistic effects are rare, but true synergistic effects are also rare, where the resulting effect of a combination is greater than the sum of the single effects of the combined products. Examples of both cases are different

Types of flame retardants:

Permanently flame-resistant polyester fibers, such as Trevira. Nomex , Kevlar are not treated with a surface flame-resistant chemical but rather the flame-resistant properties are permanently built into the molecular chain of the fiber and cannot be removed. The entire raw material is inherently flame resistant, not just the surface. Therefore, the performance cannot wear or wash off. There is no danger of toxic fumes from the curtains in the event of a fire. The flame-resistant properties are permanent and last over the lifetime of the fabric.

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs/how-trevira-cs-works.html

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs/fire-safety.html

http://livedesignonline.com/gear/staging/trevira_fabric/

METHODOLOGY

3. METHODOLOGY

The methodology for the study comprises of the following steps

- **3.1 Survey**
- **3.2 Experiment**

Survey (collection of data)

⇩

Selection of fiber

⇩

Development of yarn

⇩

Development of fabric

⇩

Testing of yarn and fabric

⇩

Development of protective clothing

3.1 Survey:

Survey may defined as Quantitative research: Statistical survey, a method for collecting quantitative information about items in a population.

The survey was conducted under the following heads

- **3.1.1Selection of area**
- **3.1.2Selection of sample**
- **3.1.3Selection of tool**
- **3.1.4Collection and consolidation of data**

- **3.1.1Selection of area**

. A survey was conducted in fire service stations around Coimbatore, to analyze the existing clothing characteristics. Coimbatore, Kinathukadavu and Pollachi towns were selected from the Coimbatore divisional office for surveying the fire fighters. Coimbatore had 6 fire stations with 60 personnel involved in administration and fire fighting; kinathukadavu and Pollachi had 2 fire stations with 20 members.

3.1.2Selection of sample:

- **Convenient sampling:**

Sampling method in which units are selected based on easy access/availability. It is also called as Accidental Sampling.

Of the 80 personnel involved in the 8 fire stations selected 50 samples were taken for the survey based on convenient sampling.

3.1.3Selection of tool (Interview schedule)

- **Interview schedule:**

Ethnographic tool for structuring a formal interview. A prepared form (usually printed or mimeographed) that guides interviews with households or individuals being compared systematically. Contrasts with a questionnaire because the researcher has personal contact with the local people and records their answers.

A sample schedule was formulated to interview the fire fighters. 10 fire fighters were interviewed and the format was reframed as given as **appendix 1**.

3.1.4Collection and consolidation of data

The fire fighters were interviewed after getting permission from the divisional officer Coimbatore. The date and time was fixed for conducting the survey based on the convenience of the fire fighters, the data was collected and consolidated as presented in the results and discussion.

3.2Experiment:

The experiment was conducted as per the experimental design given below

Survey (collection of data)

⇩

Selection of fiber (Trevira, Viscose, Cotton, Bamboo)

Blend ratio (Trevira, Viscose, Cotton , Bamboo = 40/60,50/50, 60/40,)

⇩

Development of yarn (Ring Spinning)

⇩

Development of fabric (2/1 twill)

⇩

Testing

Yarn (Strength ,Elongation, Count, Appearance, TPI)

Fabric (Physical, Mechanical, Comfort and Flammability)

⇩

Development of protective clothing

3.2.1 Selection of fiber:

Chemical finishes which impart Fire Retardancy need water, energy and effluent treatment during processing moreover the finish wears down with usage and may cause skin problems.

Flame retardant fibers like Basofil, Trevira, Kermel, and Nomex meet the important international standards on fire safety, because they consist of Properties with "Built in Safety". Trevira textiles offer long-term security against fire since the chemical structure of Trevira is slightly different from polyester fiber whereby – a phosphor-organic compound is firmly anchored in the fiber, imparting flame retardant properties, which are not affected by external influences. Trevira fibers and yarns are low-pill, micro fine, elastic, breathable, flame retardant. Hence the Trivera fibers were selected for the study. Cotton, viscose and bamboo were selected to incorporate the comfort aspect for the fire fighters clothing.

3.2.2Blend ratio:

Three different blend ratios were selected namely Trevira/ viscose, cotton, bamboo = 40/60,50/50, 60/40. The strength and elongation and flammability test was carried out and based on results the best blend ratio 50/50 was selected for the study.

Table no:1

Nomenclature of the samples:

Yarn content	Name of the sample
Trevira 100%	A
Trevira / Bamboo (50/50)	B
Trevira / Viscose (50/50)	C
Trevira / Cotton (50/50)	D

3.2.3Development of yarn:

The yarn was developed by the ring spinning method.

Ring spinning process was undertaken with the following parameters

Table No: 2

Yarn development process:

Carding: **Process:** **Licker-in speed= 0.636 rpm** **Cylinder speed = 924 rpm** **Doffer speed = 04.0 rpm** **Delivery hank = 0.5 Ne**	**Simplex:** **Spindle speed =400 rpm** **Twist = 32 TPM** **Roving count = 1.2 Ne** **Feed hank = 0.09761 Ne**
Draw Frame: **Front roller speed = 49.42 rpm** **Back roller speed = 1445 rpm** **Delivery hank = 0.9 Ne**	**Spinning:** **Spindle speed = 1000 rpm** **Roving count = 1.238486 Ne** **Count = 30s** **Twist Multiplier = 3.8** **TPI = 31.8** **Twist Direction = z** **Break Draft = 1.6**
Sizing: **Sizing material-Novacol JTS** **Single end sizing machine**	

3.2.4Development of Fabric:

The fabric was developed using 2/1 twill weave.

Weaving:

Yarns were developed in different blend proportions for the weaving process initially, then it found that 50:50 blend proportion is the suitable proportion for the development of flame retardant fabric.

Weaving:

- Weave – 2-1 twill weave
- 30s warp / 30s weft
- Fabric width – 0.5 mts

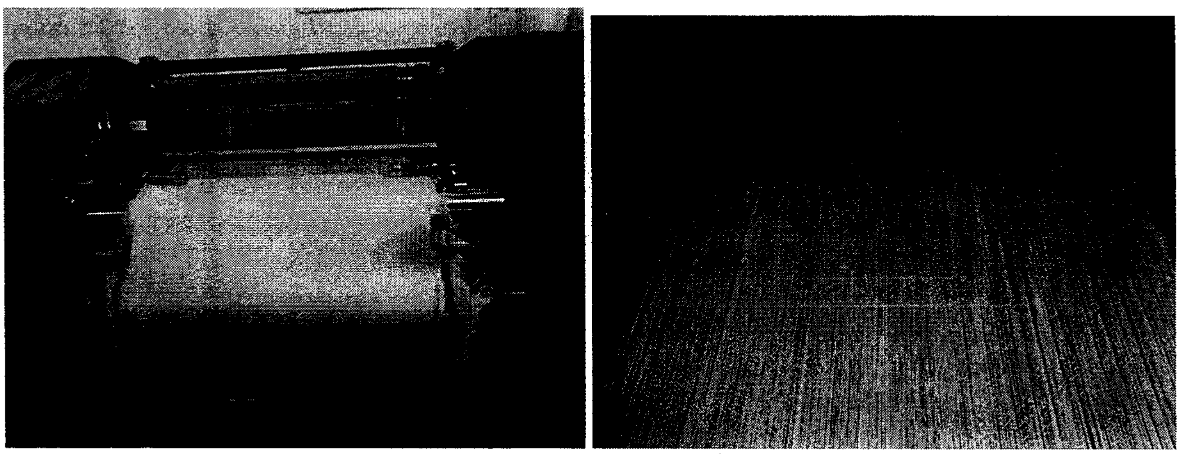


Figure 2: Development of fabric

3.2.5. Yarn testing:

3.2.5.1Count

3.2.5.2Strength

3.2.5.3Elongation

3.2.5.4Twist

3.2.5.1Count:

The term count or yarn number is commonly used to define fineness of the material. The fineness of the cotton yarn, like other solid and hard materials cannot be expressed by the measurement of its diameter because most yarns are soft and compressible. Also the cross section of the spun yarn is not fully circular and it contains variation in thickness due to presence of thin and thick places. The continuous filament yarn also suffers from this draw back.

3.2.5.2Strength:

Yarn strength is one of the important properties that decide the quality of yarn. During weaving and other processes yarn has to withstand stresses and strains. The yarn strength is decided by the factors like fibre strength , no of fibres in cross section , TPI etc.. It is also dependent on its weakest link.

In Mills the strength of the yarn is measured in terms of lea strength or skein strength and expressed as count strength product. The CSP indicates the no of leas required to break under their own weight when the leas tied one over other and hung vertically.

Instrument : Tensile strength tester (Instron Universal Tester).

Method : ASTM D2256-02.

3.2.5.3Elongation:

The Elongation of a yarn has an influence on the manufacturing process and the products made. It provides an indication of the likely stretch behavior of the garment areas such as knees, elbows or other points of stress. It also provides design criteria for stretch behavior of yarns or cords used as reinforcement for items such as plastic products , hose and tires.

A force elongation curve permit the calculation of various values, not all of which are discussed in this test method, such as elongation at break, elongation at specified force, force at specified elongation, initial elastic modules which is resistance to stretching, complaints which is ability to yield under stress, and is reciprocal of the elastic modulus, and area under the curve, a measure of toughness, which is proportional to the work done.

Force elongation curve can be converted to stress-strain curves if the force is converted to unit stress, such as to centi newtons per tex, or pounds per square inch, or pascals, or grams-force per tex,or grams force per denier, and the elongation is based on change per unit length.

3.2.5.4Twist:

Twist is introduced in to the yarn to have efficient tensile strength to withstand the stress of various spinning and weaving processes. It also binds the fibers and keeps them in position. Therefore the main function of the twist is to give coherence to the yarn. The increase in amount of twist increases the yarn strength up to a certain point beyond which further increase in twist causes the yarn to become weak and finally rupturing takes place. The diameter of the yarn is also affected by the twist it is the tendency that the thin portion of the yarn is twisted more than the thick portions. Twist is the measure of the spiral turns given to the yarn in order to hold the constituent fibers or threads together. Twist is generally expressed as the number of turns per unit length of yarn. Twist in a yarn can either be is S or Z direction.

Instrument: Single yarn twist tester

Method: ASTM D1423

3.2.6Fabric testing:

3.2.6.1Testing of physical properties:

3.2.6.2 Ends per inch (EPI):

Ends per inch (or EPI) are the number of warp threads per inch of woven fabric. In general, the higher the ends per inch, the finer the fabric is. It is very commonly used by weavers who must use the number of ends per inch in order to pick the right reed to weave with. The number of ends per inch varies on the pattern to be woven and the thickness of the thread. Plain weaves generally use half the number of wraps per inch for the number of ends per inch, whereas denser weaves like a twill weave will use a higher ratio like two thirds of the number of wraps per inch. Finer threads require more threads per inch than thick ones, and thus result in a higher number of ends per inch.

3.2.6.3. Picks per inch (PPI):

Picks per inch (or PPI) is the number of weft threads per inch of woven fabric. A pick is a single weft thread, hence the term. In general, the higher the picks per inch, the finer the fabric is. The number of picks per inch in a piece of woven cloth varies depending on what stage the cloth is at. Before the cloth is woven the weft has a certain number of picks per inch, which is directly related to what size reed. After weaving the number of picks per inch will increase, and it will increase again after being washed. This increase in the number of picks per inch and shrinkage in the size of the fabric is known as the take-up. The take-up is dependent on many factors, including the material and how tightly the cloth is woven. Tightly woven fabric shrinks more (and thus the number of picks per inch increases more) than loosely woven fabric, as do more elastic yarns and fibers.

3.2.6.4Thickness:

Thickness gauge meter is used to measure the thickness of the fabric. The gauge meter is placed in different places of fabric to analyse the thickness, the exact thickness is found out by the consolidation of the various thickness measured.

3.2.6.5GSM:

GSM = grams per square meter

Calculation:

Cut a 1 meter by 1 meter of fabric and weigh it in grams

or

weigh the fabric in grams (G) and measure the length in meters (L) and width in meters (W) and calculate:

G/LW = grams per square meter = GSM

3.2.6.6Crimp:

Crimp may be expressed numerically as the number of waves (crimps) per unit length, or as the difference between the distance between two points on the fibre when it is relaxed and when it is straightened under suitable tension, expressed as a percentage of the relaxed distance.

In woven fabric, the crimp is measured by the relation between the length of the fabric test specimen and the corresponding length of yarn when it is removed therefrom and straightened under suitable tension. The crimp may then be expressed numerically as a percentage or as a ratio, i.e. the ratio of yarn length to fabric length. In both methods, fabric length is the basis.

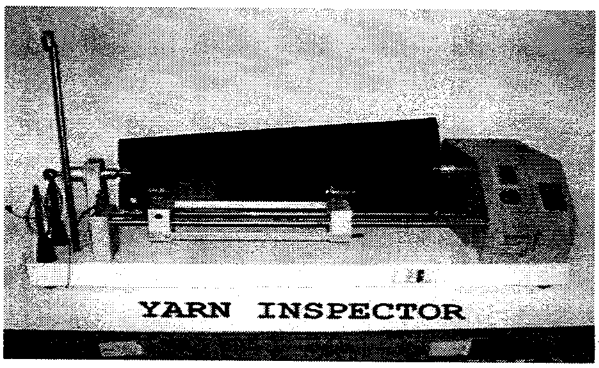
3.2.6.7Yarn Appearance:

Yarn specimens, wound on black boards, are compared with photographs of specimens representing the appearance grades. The grade is based on fuzziness, neppiness, unevenness, and visible foreign matter.

Description of Yarn Grades

Grade A, Grade B, Grade C, Grade D

Yarn Appearance Grade for Cotton yarn ASTM D2255-02.



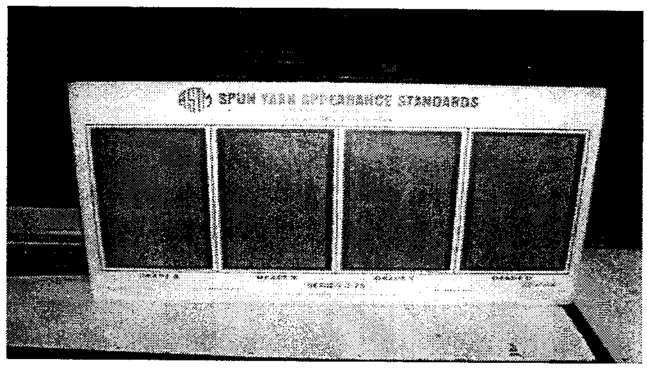


Figure 3: Yarn appearance tester with black board.

3.2.6.8 MECHANICAL PROPERTIES:

3.2.6.9 Strength and elongation:

The breaking strength is a measure of the resistance of the fabric to a tensile load or stress in either warp or weft direction. Grab test is commonly used method to determine the tensile strength of the fabric.

Fabric Tensile strength

‡ This test is used for determining the breaking strength and elongation of most textile fabrics.‡ Breaking force - the maximum force applied to a material carried to rupture.‡ Elongation - the ratio of extension of a material to the length of the material prior to stretching, expressed as percentage.‡

3.2.6.9 DRAPE:

Drape is the ability of a fabric to assume a graceful appearance in use. Drape ability of a fabric can be determined using the instrument. Drape meter and is expressed in terms of drape co-efficient. The sample can be prepared by cutting the specimen fabric to the desired size of 30 cm diameter to facilitate the fixing in the supporting disc by using a template designed as an accessory for the drape tester. The transparent lid of drape tester is opened and the supporting disc is presses down to the platform and locked at the position is taken out by un sewing rushed net. The conditional specimen is then carefully transferred and placed over the bottom supporting disc. The top supporting disc is then placed over the fabric and it made tight by securing on the knurled nut over the threaded stem of the supporting disc. Carefully Press the supporting disc by un-twisting anticlockwise. The supporting disc unit is released and allowed to raise by means of a compressed spring. This allows the edge of the fabric to drape freely under its own weight. The top level is now closed and sheet of paper size 30 cm x 35 cm is placed over it. The light is switched on .Draw the outline of the projected and area of the specimen. The formula to calculate the drape co-efficient is,

$$\text{Drape co-efficient} = \frac{\text{Drape area - small disc}}{\text{Large disc - small disc}}$$

3.2.6.10 CREASE RECOVERY TEST BS EN 22313:

Creasing of a fabric during wear is not a change in appearance that is generally desired. The ability of a fabric to resist creasing is in the first instance dependent on the type of fibre used in its construction. The essence is that a small fabric specimen is folded in two and placed under a load for a given length of time to form crease and it is allowed to recover for a further length of time and the angle of the crease that remains is measured. The magnitude of this recovery angle is an indication of the ability of a fabric recovers from accidental creasing.

In the test the specimens are folded in two, the ends being held by tweezers. Half the specimens are folded face to face and half of them back to back. They are then placed under a load for 5 min and are transferred immediately to the holder of the measuring instrument and one leg of the specimen is inserted as far as the back stop. The instrument is adjusted continuously to keep the free limb of the specimen vertical. When a fabric is creased the resulting deformation has two components: one is fibre and yarn displacement relative to one another and the second is the stretching of the fibres on the outside of the curve. The smaller the radius of curvature, the more likely it is that the fibres are actually stretched rather than the curvature being accommodated by fibre displacement.

3.2.6.11. PILLING ASTM D3511:

The formation of little fuzzy balls on a fabric surface caused by the rubbing off of loose ends of fiber too long or strong to break away entirely.To determine the pilling and fuzzing characteristics pilling tester is used. The fabrics to be tested must be wound on special pipes of Polyurethane (by means of the fitting kit) which are then placed into the cork paneled boxes. After setting the required rotation number (999999 max.) and the rotating speed (30 or 60 rpm), press the function key to start testing. Once the preset cycle is over, the pilling forming on the sample is evaluated and classified by comparison with the special set of standard photographs. When using the kit for the snagging test, the fabrics deterioration caused by the entangling into pointed materials with known characteristics is simulated.

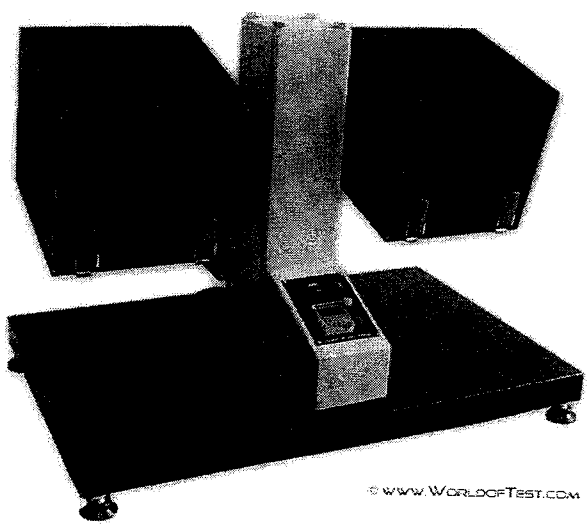


Figure 4: Pilling tester

3.2.6.12Flammability test:

Inclined flammability tester:

Flammability Tester-Inclined Plane Type

Flammability tester (Inclined Plane Type), widely used in textile industry as a standard machine to test the flammability and Flame resistance of Textiles.

Specification of the tester:

• Size of test specimen holder: 70 x 170 mm • Size of test specimen: 50 x 150 mm

Related Standard: • ASTM 2 1230-1985: Standard Test Method for Flammability of Apparel Textiles.

• BS 2963-1959 : Test for the Flammability of Fabrics Method B-and the 45 Flame Test.

• IS 11871-1986 : Methods for Determination of flammability and Flame resistance of Textiles.

• Fabrics Method – B – the 45 flame test.

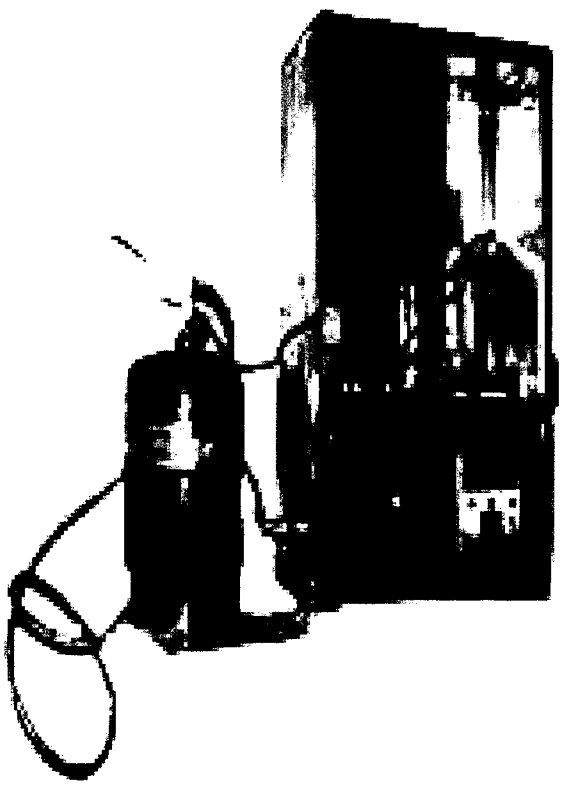


Figure 5: Inclined plane Flammability Tester

3.2.6.13 STIFFNESS TEST BS 3356:

Fabric stiffness indicates the resistance of the fabric to bending and it is a key factor in the study of handle and drape. Cantilever principle of working is used to determine the stiffness of fabrics stiffness is related with handle and drape of the fabric. A sample size of 6" X 1" is cut 10 samples in warp way and weft way direction. The tester is cut on a table, so that the horizontal platform and the index lines are at eye level. The specimen is placed in between the platform and the template so that the fabric and the zero mark of the template coincides with the datum line. Both template and fabric are slowly pushed forward. The fabric will tend to drop are the edge on its own weight. Both are moved forward until the tip of the fabrics cuts the index lines when viewed in the mirror. The bending length is measured from the scale. From the above readings flexural rigidity is calculated using the formula:

Flexural Rigidity = (Weight of the sample * Bending length *10^3) mg.cm

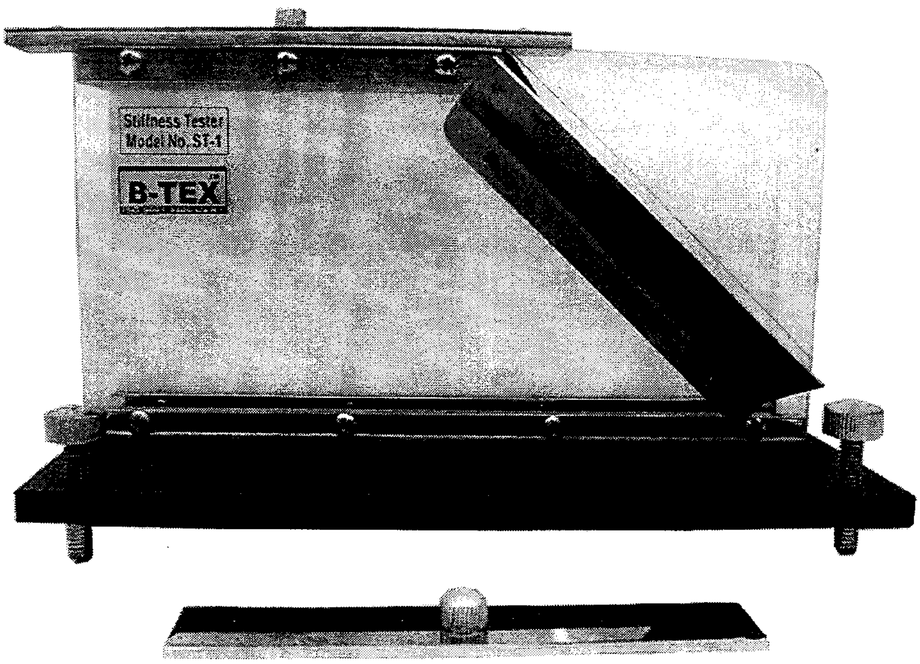


Figure 6: Stiffness tester

3.2.6.14 TESTING OF COMFORT PROPERTIES:

3.2.6.15. AIR PERMEABILITY ASTM D2752:

Air permeability is an important property for woven and it depends on many parameters of the fabric. The porosity of a fabric as estimated by the ease with which air passes through it. The pilot test must be performed long enough to evacuate a minimum of 1.5 - 2 pore volume of air in order to gather sufficient and representative data.

This typically can be accomplished within 8 to 12 hours of test operation. The tests need to be conducted for a long enough period of time for the measured vacuums and extracted concentrations to reach equilibrium conditions. Initial extracted concentrations observed are not indicative of equilibrium conditions and tend to be higher than during system operation. Sufficient steps should be performed in order to adequately establish the relationship between vacuum, air flow rates and the mass removal rate.

The highest vacuum step applied should be at the maximum capabilities of the air pump or blower used. Lower vacuum step tests should also be performed, because results from operating at the vacuum extremes helps to determine the vacuum required obtaining optimum mass removal rates. Changes in barometric pressure should be monitored at the beginning and end of each vacuum step, in order to determine baseline shifts in apparent vacuum.

Vacuum monitoring readings should be taken at wells and/or probes at nominal 15 minute intervals through each vacuum step. Air flow rates should be measured at the extraction well frequently throughout each vacuum step in order to document any increase or decrease in flow. Blowers/vacuum pumps need to have explosion proof motors, starters, and electrical systems.

Figure 7: Air Permeability Tester

3.2.6.16WATER VAPOUR PERMEABILITY:

The water vapour permeability is the measure for breathability for a textile's ability to transfer moisture. The water vapour permability tester is capable of holding 8 samples. Evacuate the air from the sealing tube / membrane cavity. Testing of water permeability should be performed in stable ambient conditions. It is assumed, that ambient conditions are stable if temperature and humidity are within specified thresholds. It has a nut of circular opening in which the samples are mounted on the sample holders which rotate at specified revolution per minute with the help of motor pulley & belts. A moisture analyzer should be plugged to mains at least 30 minutes before test initiation. Distilled water that is used for the test should have temperature close to ambient temperature of test room. Water should be stored in test room for at least 24 hours before test procedure initiation for its thermal stabilization.

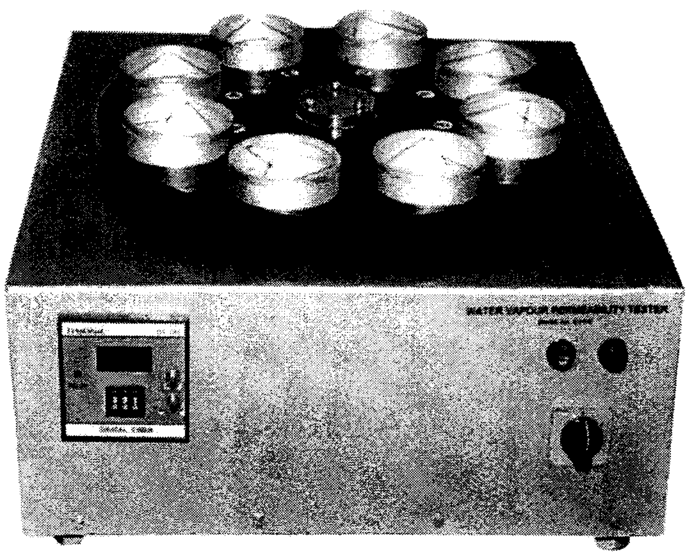


Figure 8: Water Vapor permeability tester

3.2.6.17 THERMAL RESISTANCE:

Thermal resistance is a heat property and a measure of a temperature difference by which an object or material resists a heat flow (heat per time unit or thermal resistance). Thermal resistance is the reciprocal thermal conductance.

- **Thermal resistance** R has the units $(m^2K)/W$.
- **Specific thermal resistance** or **specific thermal resistivity** R_λ in $(K \cdot m)/W$ is a material constant.
- **Absolute thermal resistance** R_{th} in K/W is a *specific* property of a component. It is e.g., a characteristic of a heat sink

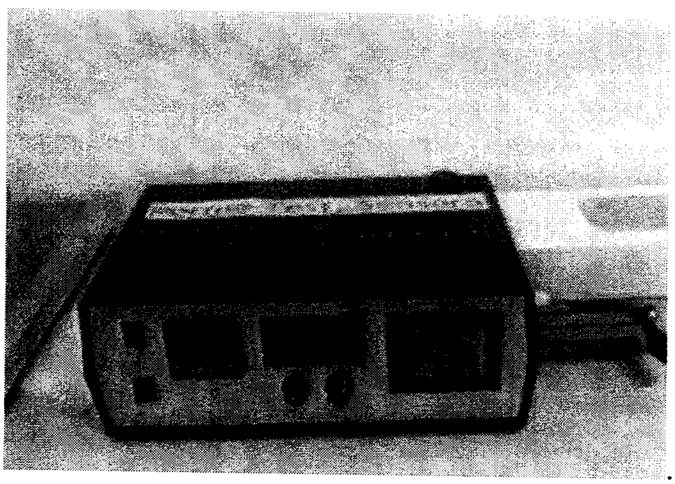


Figure 9: Thermal Resistance Tester

3.2.6.18 SPRAY TEST:

The water repellency is tested with a so called spray test according to the **ISO 4920**. The Evaluation of the test is visual appreciation of the surface of the fabric (number of absorption points on the surface). The repellency of a garment worn in foul weather conditions is very important. A good repellency will increase the comfort during use. The repellency tends to decrease during washing, so a re-impregnation of a water repellent product is advised.

The method is applicable to all fabrics which may or may not have been given a water-resistant or water-repellent finish. It is not intended to predict the rain penetration resistance of fabrics, since it does not measure penetration of water through the fabric. Before testing carried out the specimen shall be conditioned for at least 24h in the standard atmosphere for testing textiles. Spray test:

GRADE: RESULTS

70ISO2: Partial wetting of specimen face beyond the spray points.

0 : complete wetting of the entire face of the specimen

50ISO1 : Complete wetting of the entire specimen face beyond the spray points.

Figure 10: Spray Rating Tester

3.3 STATISTICAL ANALYSIS:

3.3.1 ANOVA: Analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. Doing multiple two-sample t-tests would result in an increased chance of committing a type I error. For this reason, ANOVAs are useful in comparing two or more means.

There are several types of ANOVA. Many statisticians base ANOVA on the design of the experiment, especially on the protocol that specifies the random assessment of treatments to subjects; the protocol's description of the assignment mechanism should include a specification of the structure of the treatments and of any blocking. It is also common to apply ANOVA to observational data using an appropriate statistical model.

Some popular designs use the following types of ANOVA:

- One-way ANOVA is used to test for differences among two or more independent groups. eg. Different levels of urea application in a crop. Typically, however, the one-way ANOVA is used to test for differences among at least three groups, since the two-group case can be covered by a t-test. When there are only two means to compare, the t-test and the ANOVA F-test are equivalent; the relation between ANOVA and t is given by $F = t^2$.
- Factorial ANOVA is used when the experimenter wants to study the interaction effects among the treatments.
- Repeated measures ANOVA are used when the same subjects are used for each treatment.

IMPORTANCE OF ANOVA:

Analysis of variance (ANOVA) is defined as the "Separation of variance ascribable one group of cause from the variance ascribable to another group".

- ANOVA is the most powerful statistical tools.
- ANOVA is general method of analyzing data from designed experiments.
- ANOVA is a powerful process that is useful to analyze the variance between any number of sample.

- ANOVA is useful to find significance level between any number of samples and we can analyze whether difference is statistically significant (or) not
- This is specially useful to give conclusions for the data obtained in researches.
- It is most powerful than t-test as it has no limit in samples that we analyze, T-test is useful to analyze up to only 30 samples

The method of ANOVA tests the hypotheses that:

H_0: $\mu_1 = \mu_2 = \mu_3, = \ldots = \mu_k$ or **H_a**: Not all the means are equal

ANOVA table – Basic layout:

Source	**Sum of squares (SS)**	**Degree of freedom (df)**	**Mean Square**	**F-statistics**	**P-value**
Between samples	SSB	k-1	$MSB = \frac{SSB}{k-1}$	$F = \frac{MSB}{MSE}$	Value from table
Within samples	SSE	n-k	$MSE = \frac{SSE}{n-k}$		
Total	SSTO	n-1			

Acceptance Criteria for the Null Hypothesis:

If the F-statistics computed in the ANOVA table is less than the F-table statistics or the P-value if greater than the alpha level of significance, then there is not reason to reject the null hypothesis that all the means are the same.

That is **accept H_0** if: **F-Statistics < F-table** or **P-value > alpha.**

Thus, this test uses the F-distribution (probability distribution) function and information about the variances of each population (within) and grouping of populations (between) to help decide if variability between and within each populations are significantly different.

3.3.2CHI SQUARE TEST:

Pearson's chi-squared test (χ^2) is the best-known of several chi-squared tests – statistical procedures whose results are evaluated by reference to the chi-squared distribution. Its properties were first investigated by Karl Pearson in 1900. In contexts where it is important to make a distinction between the test statistic and its distribution, names similar to **Pearson X-squared** test or statistic are used.

It tests a null hypothesis stating that the frequency distribution of certain events observed in a sample is consistent with a particular theoretical distribution. The events considered must be mutually exclusive and have total probability 1. A common case for this is where the events each cover an outcome of a categorical variable. A simple example is the hypothesis that an ordinary six-sided die is "fair", i.e., all six outcomes are equally likely to occur.

Definition

Pearson's chi-squared is used to assess two types of comparison: tests of goodness of fit and tests of independence.

- A test of **goodness of fit** establishes whether or not an observed frequency distribution differs from a theoretical distribution.
- **A test of independence** assesses whether paired observations on two variables, expressed in a contingency table, are independent of each other—for example, whether people from different regions differ in the frequency with which they report that they support a political candidate.

The first step is to calculate the chi-squared test statistic, X^2, which resembles a normalized sum of squared deviations between observed and theoretical frequencies (see below). The second step is to determine the degrees of freedom, d, of that statistic, which is essentially the number of frequencies reduced by the number of parameters of the fitted distribution. In the third step, X^2 is compared to the critical value of no significance from the χ^2_ddistribution, which in many cases gives a good approximation of the distribution of X^2. A test that does not rely on this approximation is Fisher's exact test; it is substantially more accurate in obtaining a significance level, especially with few observations.

Test for fit of a distribution

Discrete uniform distribution

In this case N observations are divided among n cells. A simple application is to test the hypothesis that, in the general population, values would occur in each cell with equal frequency. The "theoretical frequency" for any cell (under the null hypothesis of a discrete uniform distribution) is thus calculated as

$$E_i = \frac{N}{n},$$

and the reduction in the degrees of freedom is $p = 1$, notionally because the observed frequencies O_i are constrained to sum to N.

Other distributions

When testing whether observations are random variables whose distribution belongs to a given family of distributions, the "theoretical frequencies" are calculated using a distribution from that family fitted in some standard way. The reduction in the degrees of freedom is calculated as $p = s + 1$, where s is the number of parameters used in fitting the distribution. For instance, when checking a 3-parameter Weibull distribution, $p = 4$, and when checking a normal distribution (where the parameters are mean and standard deviation), $p = 3$. In other words, there will be $n - p$ degrees of freedom, where n is the number of categories.

It should be noted that the degrees of freedom are not based on the number of observations as with a Student's t or F-distribution. For example, if testing for a fair, six-sided die, there would be five degrees of freedom because there are six categories/parameters (each number). The number of times the die is rolled will have absolutely no effect on the number of degrees of freedom.

Calculating the test-statistic

The value of the test-statistic is

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

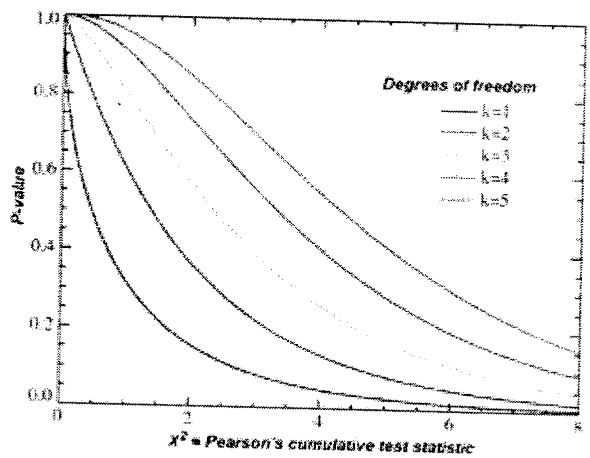
where

X^2= Pearson's cumulative test statistic, which asymptotically approaches a χ^2 distribution.

O_i= an observed frequency;

E_i= an expected (theoretical) frequency, asserted by the null hypothesis;

n= the number of cells in the table.



Chi-squared distribution, showing X^2 on the x-axis and P-value on the y-axis.The chi-squared statistic can then be used to calculate a p-value by comparing the value of the statistic to a chi-squared distribution. The number of degrees of freedom is equal to the number of cells n, minus the reduction in degrees of freedom, p.The result about the number of degrees of freedom is valid when the original data was multinomial and hence the estimated parameters are efficient for minimizing the chi-squared statistic. More generally however, when maximum likelihood estimation does not coincide with minimum chi-squared estimation, the distribution will lie somewhere between a chi-squared distribution with $n - 1 - p$ and $n - 1$ degrees of freedom (See for instance Chernoff and Lehmann, 1954).

Bayesian method

In Bayesian statistics, one would instead use a Dirichlet distribution as conjugate prior. If one took a uniform prior, then the maximum likelihood estimate for the population probability is the observed probability, and one may compute a credible region around this or another estimate.

Test of independence

In this case, an "observation" consists of the values of two outcomes and the null hypothesis is that the occurrence of these outcomes is statistically independent. Each observation is allocated to one cell of a two-dimensional array of cells (called a table) according to the values of the two outcomes. If there are r rows and c columns in the table, the "theoretical frequency" for a cell, given the hypothesis of independence, is

$$E_{i,j} = \frac{\left(\sum_{n_c=1}^{c} O_{i,n_c}\right) \cdot \left(\sum_{n_r=1}^{r} O_{n_r,j}\right)}{N},$$

where N is the total sample size (the sum of all cells in the table). The value of the test-statistic is

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{(O_{i,j} - E_{i,j})^2}{E_{i,j}}.$$

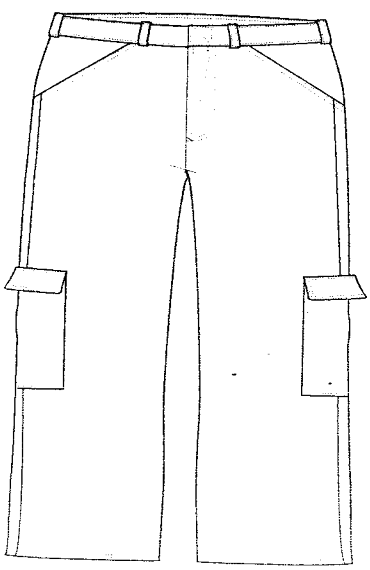
Fitting the model of "independence" reduces the number of degrees of freedom by $p = r + c - 1$. The number of degrees of freedom is equal to the number of cells rc, minus the reduction in degrees of freedom, p, which reduces to $(r - 1)(c - 1)$.

For the test of independence, also known as the test of homogeneity, a chi-squared probability of less than or equal to 0.05 (or the chi-squared statistic being at or larger than the 0.05 critical point) is commonly interpreted by applied workers as justification for rejecting the null hypothesis that the row variable is independent of the column variable. The alternative hypothesis corresponds to the variables having an association or relationship where the structure of this relationship is not specified.

3.4 Development of Protective Clothing:

The fabric based on its properties is selected for the development of clothing. Design is created accordingly to the feedback given by the respondents..

Figure 11-Design of the protective wear



RESULT&DISCUSSION

4. RESULTS AND DISCUSSION

The results of the study are discussed under the following heads

4.1 Survey

4.2 Experiment

4.1 Survey:

- From the survey it can be understood that
- 99% of the fire fighters surveyed wore normal cotton clothing during fire fighting.
- Since the fabric is cotton, the flame Retardancy aspect is negligible. This gives rise to the need for protective clothing.
- 99 % of the respondents wanted change in design which would be incorporated in the study.
- When the health and hazard aspects were taken in to consideration with clothing characteristics, a positive association was found using the chi square test highlighting the fact that protective clothing is essential for health and safety of fire fighters.

Table no: 3
Details pertaining to nature of job and hazards faced during fire fighting

Training	Yes =98%	No =2%		
Nature of job	Fire fighters=60%	Supervisory= 22.5%	Administration= 17.5%	
Health	Respiratory =32.5%	**Skin rashes=57.5%**	Fire wounds=50%	Nervous problems=30%
hazards	**Physical=80%**	Chemical=45%	Biological= 17.5%	Electrical= 22.5%
Clothing	**Normal=99%**	Protective=1%		
Awareness	**Yes= 98%**	No =2%		
Requirement of protective clothing	**Yes=99%**	No=1%		

- 99% of the fire fighters surveyed wore normal cotton clothing during fire fighting. The nature of job brought about many problems in health like respiratory skin rashes (57.5%), fire wounds and nervous problems. The hazards faced during fire fighting were physical (80%), chemical and biological in nature.
- Awareness for the requirement of protective clothing was felt by 98% of the fire fighters surveyed.

Table no:4

Existing clothing characteristics

Characteristics	Excellent	Good	Average	Satisfactory	Poor
Confidence level	0%	37%	**53%**	10%	0%
Weight & Thickness	7%	20%	**53%**	18%	2%
stiffness	7%	40%	**33%**	18%	2%
Flame resistance	3%	12%	**53%**	30%	2%
Tear resistance	0%	10%	**65%**	23%	2%
Water repellency	0%	20%	**56%**	23%	1%
Style	0%	13%	**32%**	50%	5%
Design	0%	22%	**28%**	45%	5%
Life	2%	23%	**40%**	35%	0%
Safety	0%	10%	**78%**	12%	0%

- Table shows that the existing clothing characteristics are within the average limit as mentioned by the respondents shown above. 78% of the fire fighters felt that the safety aspect was in the average level. and the design was preferred by 28% as average. This calls for better designing of garment and more safety aspects are to be included.

Chi square Test:

Table no: 5
Checking association between the characteristics

Characteristics -1	Characteristics -2	Pearson chi square	Sigma
Flame Retardancy	Health	7.322	0.007
Flame Retardancy	Hazards	4.483	0.034
Water Repellency	Health	6.988	0.008
Water Repellency	Hazards	3.515	0.045

HO- There is no association between health problems and clothing characteristics.
Ha - There is association between health problems and clothing characteristics

- Table shows that the sigma value is lower than 0.05 which means REJECT H0 accepting Ha.
- Hence there is association between health problems and clothing characteristics.

4.2 Experiment:

The results of the experiment for the study are discussed under the following heads:

Physical properties:
EPI, PPI, Thickness, GSM, Crimp, Yarn appearance –Grade

Mechanical properties:
Strength& Elongation, Drape, Crease recovery, Pilling Resistance, Flame Retardancy, Stiffness.

Comfort properties:
Air permeability, Water vapor, Thermal resistance, Spray test,

Physical properties:

Table No: 6
Physical properties of Trevira and its blends.

S. NO	Name of the test	Control Trevira1 00% (A)	Trevira/ Bamboo (50/50) (B)	Gain or loss over control	Trevira/ viscose (50/50) (C)	Gain or loss over control	Trevira/ Cotton (50/50) (D)	Gain or loss over control
1	EPI	98	100	-2.04	96	2.04	98	0
2	PPI	66	66	0	66	0	67	-1.5
3	Thickness (mm)	0.40	0.35	5	0.38	12.5	0.39	2.5
4	GSM (Grams)	169.1gms	145.2gms	14.1	146.6gms	13.3	152gms	10.11
5	Crimp warp weft(%)	7% 3%	7% 3%	0 0	6% 4%	14.2 33.3	7% 5%	0 66
6	Yarn appearance –Grade	A	B		A		B	

- The table shows that the EPI had a mixed response, and PPI showed no change in values. The overall thickness and GSM reduced in all the three blends when compared to the control. The Annova table shows that PPI, crimp was significant at 5% level whereas the Thickness, EPI, GSM showed values significant at 1% level.

Annova Table:

EPI	Source of variation	SS	df	Ms	F value
	Between Groups	29.2	3	9.733333	9.733333**
	Within Groups	16	16	1	
PPI	Between Groups	13.2	3	4.4	2.75*
	Within Groups	25.6	16	1.6	
Thickness	Between groups	0.00 5119	3	0.00170	8.1089**
	Within groups	0.00 252	12	0.00021	
GSM	Between Groups	1667.344	3	555.7813	667.2045**
	Within Groups	13.328	16	0.833	
Crimp	Between Groups	2.95	3	0.983333	1.573333*
	Within Groups	10	16	0.625	
**significant at 1% level	* significant at 5% level				

Table No: 7

Mechanical properties of Trevira and its blends

Experiment:

The results of the experiment for the study are discussed under the following heads:

S. NO	Name of the test		Control Trevira100% (A)	Trevira/Bamboo(50/50) (B)	Gain or loss over control	Trevira/viscose (50/50) (C)	Gain or loss over control	Trevira/Cotton (50/50) (D)	Gain or loss over control
1	Strength & Elongation (gf/tex)	Warp	23.58	22.92	2.7%	32.37	-37.27%	24.98	-5.9%
		Weft	13.65	12.81	6.15%	20.52	-50.32	13.18	3.44%
2	Drape %	Face	141.27	157.27	-11.3%	136.27	3.53%	108.27	23%
		Back	144.27	153.27	-6.2%	115.27	20.1%	110.27	23.5%
3	Crease Recovery %	Warp	75.6	64.6	14.5%	62	17.9%	65.4%	13.4%
		Weft	97.2	104.2	-7.2%	85.6	11.9%	84.4	13.1%
4	Pilling Resistance (Grade)		SM54 GRADE 4	GRADE 5		GRADE 4		GRADE 3	
5	Flammability(in secs)		15	14	7.1%	11	26.6%	14	7.1%
6	Stiffness (cm)	Warp	3.3	2.7	18%	2.5	24%	2	39%
		Weft	2.3	2.1	8.6	1.9	17%	2	13.04% S

- The table shows that the Strength, Drape, Crease, Flame, stiffness had a mixed response, and showed no change in values. The overall Crease, Flame, stiffness reduced in all the three blends when compared to the control. The Annova table shows that Stiffness was significant at 5% level whereas the Strength, Drape, Crease, Flame showed values significant at 1% level.

Annova table:

Crease recovery	Source of variation	SS	Df	Ms	F value
	Between Groups	536.2	3	178.7333	28.71218**
	Within Groups	99.6	16	6.225	
Strength and elongation-warp	Between Groups	231.7801	3	77.26003	17.29788**
	Within Groups	71.46312	16	4.466445	
Weft	Between Groups	117.7329	3	39.2443	11.62188**
	Within Groups	54.02816	16	3.37676	
Drape –FACE	Between Groups	1249	3	416.3333	65535**
	Within Groups	0	0	65535	
Drape –back	Between Groups	12758.75	3	4252.917	64535**
	Within Groups	0	0	65535	
Stiffness - warp	Between Groups	2.8625	3	0.954167	286.25**
	Within Groups	0.026667	8	0.003333	
Stiffness – weft	Between Groups	0.04	3	0.013333	0.64*
	Within Groups	0.166667	8	0.020833	
Flammability	Between Groups	9	3	3	65535**
	Within Groups	0	0	65535	
**significant at 1% level				* significant at 5% level	

Table no:8
Comfort properties of Trevira and its blends

The results of the experiment for the study are discussed under the following heads:

S.NO	Name of the test	Control Trevira100% (A)	Trevira/Bamboo(50/50) (B)	Gain or loss over control	Trevira/viscose (50/50) (C)	Gain or loss over control	Trevira/Cotton (50/50) (D)	Gain or loss over control
1	Air permeability (l/min)	63.27	75.52	- 19.36%	105.48	- 66.71%	59.45	6.03%
2	Water vapor	5.02	5.13	-2.39%	5.30	-5.57%	4.91	2.19%
3	Thermal Resistance (m^2k/w)	0.0714	0.0724	-1.40%	0.0743	-4.0	0.0728	-1.9%
4	Spray Test(grade)	70ISO2	0		0		50ISO1	

- The table shows that the Air permeability had a mixed response, and Thermal Resistance, water vapor showed no change in values. The overall Air permeability and Thermal Resistance reduced in all the three blends when compared to the control. The Annova table shows that vapor, Thermal Resistance was significant at 5% level whereas Air permeability showed values significant at 1% level.

Annova table:

Name of the test	Source of variation	SS	Df	Ms	F value
Air permeability test	Between groups	13113.43	3	4371.143	161.117**
	Within groups	976.686	36	27.13	
Water vapor test	Between groups	2.094825	3	0.698275	0.681039*
	Within groups	8.202467	8	1.025308	
Thermal resistance	Between groups	0.0000129	3	0.0000043	0.807*
	Within groups	0.0000638	12	0.00000532	
**significant at 1% level	* significant at 5% level				

CONCLUSION

5. SUMMARY AND CONCLUSION

Trevira textiles meet the important international standards on fire safety, because they consist of fibers and yarns with built-in safety. The development of fibers and fabrics focusing on flame retardant is useful for many technical applications. Trevira is environmentally friendly with an Oekotex 100 certificate stating the material contains no harmful substances. National and international standards regulate protection against fire.

Based on the above criteria study is done by the following objectives

- To collect data about requirements of clothing for fire fighters in and around Coimbatore.
- Fiber blending and Yarn development.
- Development of fabric with improved performance properties.
- Testing of Yarn and Fabric (physical, mechanical, comfort, flame retardant properties)
- Design and development of Protective wear.

METHODOLOGY

A Survey was conducted for the fire fighters. The raw Trevira fiber was blended with cotton, viscose and bamboo in a blend proportion (50:50) and converted to yarn by the Ring spinning process. The Trevira yarn and its blends were used to develop 2/1 Twill fabric with a Mini Projectile loom. The developed fabric was tested for Physical, Mechanical and comfort properties.
A model of the fire fighters protective wear was developed based on the suggestions given by the respondents during the survey.

FINDINGS of THE STUDY

SURVEY

- 99% of the fire fighters surveyed wore normal cotton clothing during fire fighting.
- The nature of job brought about many problems in health like respiratory skin rashes (57.5%), fire wounds and nervous problems.
- The hazards faced during fire fighting were physical (80%), chemical, biological in nature. An awareness for the requirement of protective clothing was felt by 98% of the fire fighters surveyed.
- 78% of the fire fighters felt that the safety aspect was in the average level. and a change in design was preferred by 28% as average. This call for better designing of garment and more safety aspects are to be included.

EXPERIMENT:

- The strength and elongation of the Trevira 100% is higher when compared to other blends this also shows improved Thickness and GSM factors of the same.
- EPI and PPI of all blends are almost same this shows that comfort properties of the blends remains almost same.
- Flammability property is higher in Trevira 100% when compared to its blends.
- Trevira/bamboo show good air permeability, water vapor when compared to other fabric Samples.
- Thermal resistance property is higher in Trevira 100% fabric when it is compared to its blends.
- Trevira /bamboo, viscose blends shown higher wetting property in spray rating test.
- Trevira/viscose has higher Drape ability when compared to other blends.
- Trevira/ Bamboo has higher pilling resistance when compared toother fabric samples.

CONCLUSION

From the study it can be concluded that 100% Trevira fabric showed the best flame Retardancy property since it had 100% Trevira fiber. A combination of comfort and flame Retardancy was found to be best in Trevira/viscose (50:50) blended fabric when compared to the other blends. Hence these fabrics can be selected for protective wear depending on the end use.

Development of protective clothing for fire fighters is important to protect fire fighters from flame and hazards. Chemical finishes that are imparted to the fabric for Flame Retardancy bring some effects like skin rashes and health problems to the wearer, and it does not tend longer with its properties. Thus fibers like Trivera and nomex which have inbuilt Flame Retardancy are used for development of protective clothing. The blending ratio is formalized based upon the requirements of comfort properties which are to be imparted in the clothing. Such fabrics with flame Retardancy can also be used for home furnishings, technical textiles etc..

LIMITATIONS

- While surveying in fire service station, the workers did not give information because of governmental pressure
- No availability of Trevira fiber in local market
- No proper testing equipment available for testing flammability

RECOMMENTATIONS FOR FUTURE STUDY

- To blend with other fibers in different blend ratio
- To develop flame retardant fabric for home textiles and nightwear
- To dye the fabric with eco friendly dyes

REFERENCE

6. REFERENCE:

REFERENCES

Abbot, N.J. and Schulman, S.,(*July 1976,*) "Protection from Fire: Nonflammable Fabrics and Coatings,"*J. Coated Fabrics, Vol. 6, pp.48-62*

David Torvi and George Hadjisophocleous (1991) Research Need in Protective Clothing. Institute For Research In Construction. Serthi R427.

WEBSITES

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs.html

http://www.kermel.com/site/Production-of-High-Tech-non-flammables-Fibres-640.html

http://en.texsite.info/Anti-soiling_finish%3B_soil-resistant_finish%3B_soil-repellent_finish

http://psasir.upm.edu.my/2379/1/Effects_of_Soil-repellent_and_Smolder-resistant_Finishes,.pdf

http://www2.dupont.com/personal-protection/en-us/dpt/kevlar.html

http://cotton.missouri.edu/Classroom-Comfort.html

http://www.fibre2fashion.com/industry-article/textile-industry-articles/properties-of-bamboo-fibre/properties-of-bamboo-fibre1.asp

http://en.wikipedia.org/wiki/Ring_spinning

http://en.wikipedia.org/wiki/Weaving

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs/how-trevira-cs-works.html

http://www.trevira.de/en/textiles-made-from-trevira/home-textiles/flame-retardant-textiles-trevira-cs/fire-safety.html

http://livedesignonline.com/gear/staging/trevira_fabric/

APPENDIX

Appendix:

Appendix-1- Questionnaire

Survey

Development of fire fighters protective clothing

1. Name of the station: 2. Person In charge:

3. Name:

4. Age: a.25-30 b.31-35 c.36-40 d.41&above

5. Experience: a.1-5 b.6-10 c.11-15 d.16& above

6. Have you undergone any Training so far: yes/ no

7. Nature of the job:

a. Administration b. Supervisory c. Fire Fighters

8. Health: a. Respiratory problems b. Skin rashes c. Fire wounds d. Nervous problems

9. Hazards: a. Physical b. Chemical c.Biological d.Electrical

10. Which of the following was provided to you?
 a. Normal clothing b.Specially finished clothing c.Protective clothing
 d. Special accessories [helmet, gloves, etc]

11. Existing clothing characteristics:

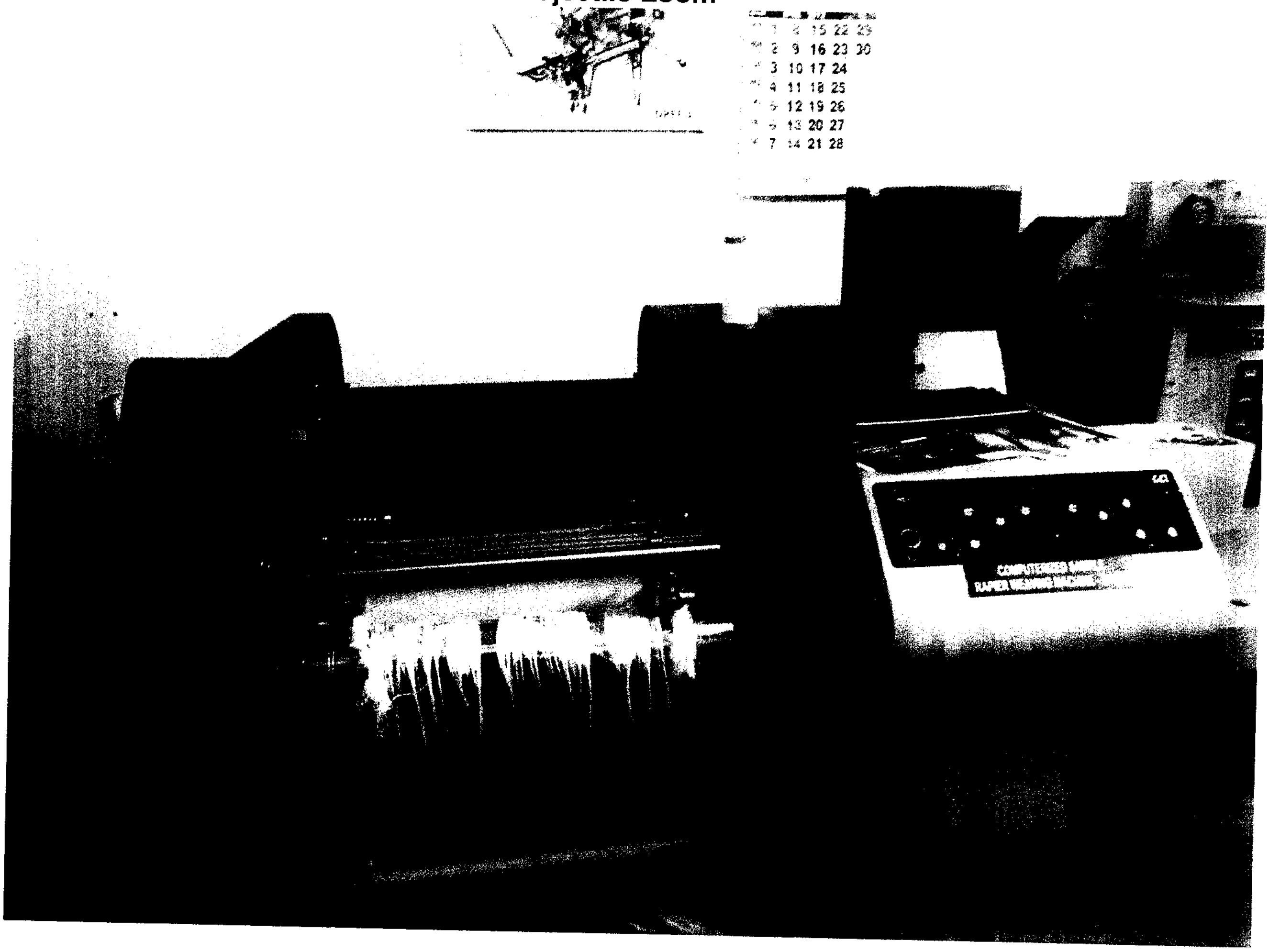
Characteristics	Excellent	Good	Normal	satisfactory	poor
Confidence level					
Weight & Thickness					
Stiffness					
Flame resistance					
Tear resistance					
Water repellency					
Style					
Design					
Life of clothing					
Replacement					
Safety					

12. Are you aware of clothing standards for firefighting: yes / no

13. Do you require protective clothing? Yes / no

14. How would like your uniforms to be designed?
 Suggestions:

Appendix 2 – Fabric Formation Mini Projectile Loom



Appendix-3
Protective clothing