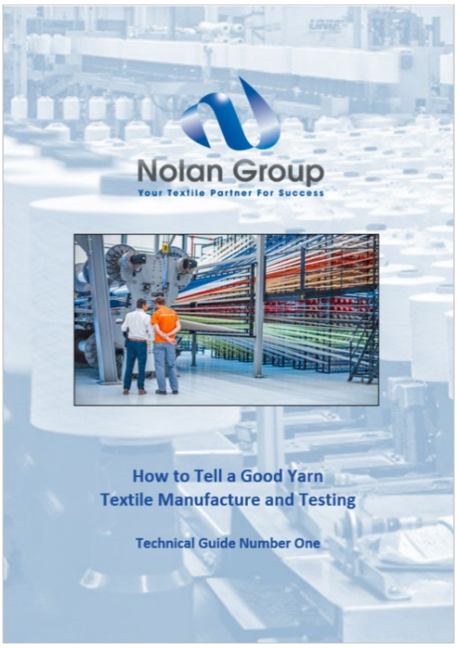
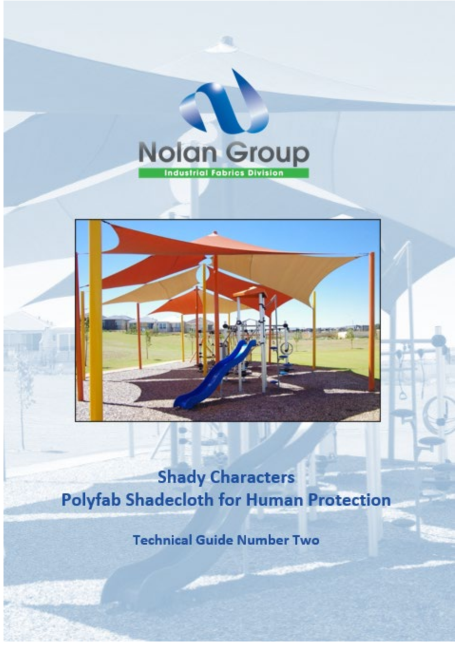
Nolan Group

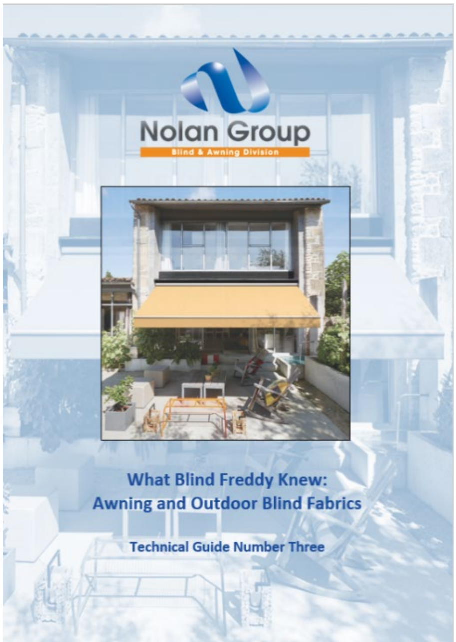
Industrial Fabrics Division

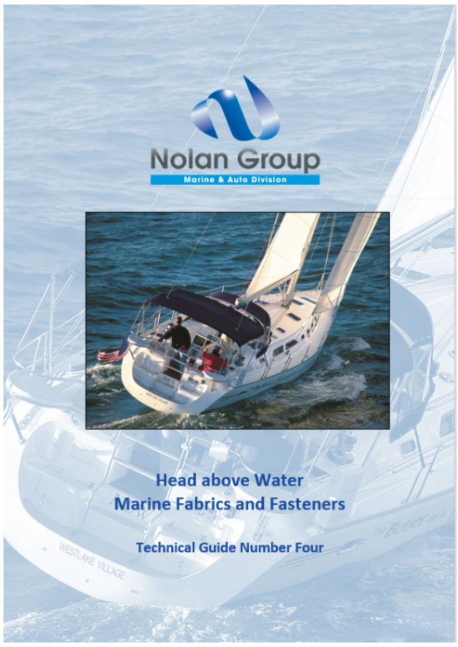
Got You Covered
Polycotton Canvas,
Coated or Laminated Industrial and Architectural Fabrics

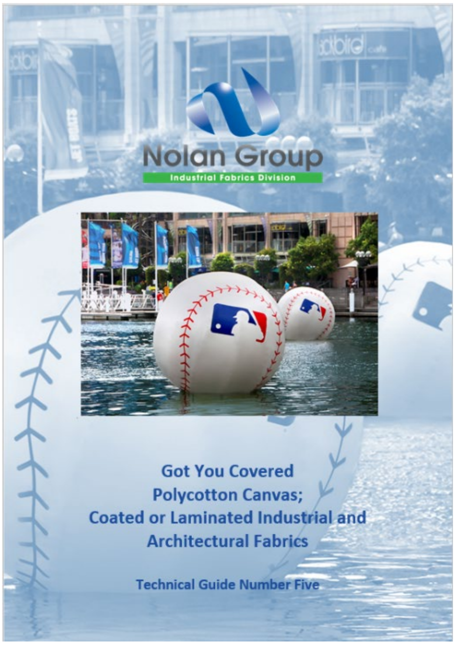
Technical Guide Number Five


Nolan Group
Your Textile Partner For Success
How to Tell a Good Yarn
Textile Manufacture and Testing
Technical Guide Number One


Nolan Group
Industrial Fabrics Division
Shady Characters
Polyfab Shadecloth for Human Protection
Technical Guide Number Two


Nolan Group
Blind & Awning Division
What Blind Freddy Knew:
Awning and Outdoor Blind Fabrics
Technical Guide Number Three


Nolan Group
Marine & Auto Division
Head above Water
Marine Fabrics and Fasteners
Technical Guide Number Four


Nolan Group
Industrial Fabrics Division
Got You Covered
Polycotton Canvas;
Coated or Laminated Industrial and
Architectural Fabrics
Technical Guide Number Five


Nolan Group
Commercial Division
Not Flawed
Commercial Carpet, Carpet Tiles and Acoustics
Technical Guide Number Six

Got You Covered

Polycotton Canvas, Coated or Laminated Industrial and Architectural Fabrics

Technical Guide Number Five

Second Edition, First Printing May 2020

Cover photo: Promotion for opening game of the US Major League Baseball season, which was played in Sydney in 2014, the teams being the LA Dodgers and the Arizona Diamondbacks. The inflatables are fabricated from Protex GP Coated PVC.

About the Nolan Group

Nolan.UDA Pty Ltd, now trading as the Nolan Group, was officially incorporated in 2009. It originally comprised the merger of the trading operations of Nolan O'Rourke and Co. Pty Ltd (trading as Nolan Warehouses) and Upholstering Distributors Australia Pty Ltd as a 50-50 joint venture, and hence the company name.

In 2016, the Business of Radins Australia Pty Ltd was formally integrated into the company. Despite its hybrid nature and relatively short history, the Nolan Group has a proud legacy inherited from its constituent partners.

Nolan O'Rourke was established in 1920 by William Bernard Nolan, and is still third generation family owned. The company had its beginnings importing Motor Body Parts and Accessories, but over the years, it diversified first into wholesaling upholstery and furnishing supplies; and then related products in Marine and Motor Trim, Industrial Textiles and Commercial Flooring markets.

A delivery vehicle at Circular Quay, Sydney circa 1930

Upholstering Distributors Australia Pty Ltd (UDA) is itself a subsidiary of a fourth generation family company, Thomas Peacock and Sons, established in 1881. The principal operations of that group are the manufacture of Bedding, expanded foam and lofted polyester.

These two businesses were well suited to merger. They were of similar size, operated in a like fashion, sold comparable (some identical) products to the same market segments in overlapping geographic areas. They complemented each other well, especially in terms of relative market penetration by both product type and geographic location.

Importantly, the partnering businesses were well established, had an excellent reputation and a high level of mutual respect, mainly because of similarities in their cultures and business approach.

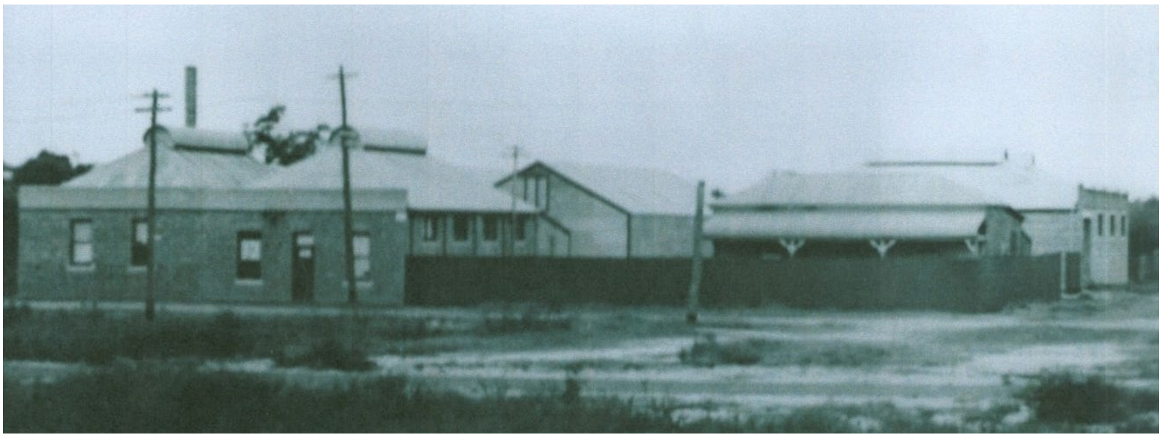
The success of the original merger led to the Radins' acquisition. Radins had its origins in the nineteenth century as a sailmaker, and the morphing into a wholesale distributor occurred gradually, with the fabrication arm sold off in the early nineties. The company's specialty was fabric supply to the awning and blind sector, complemented by a significant presence in Marine and Industrial Fabrics.

The business of Polyfab Australia was acquired in 2017. Originally founded in 1995, the company had developed a number of innovative knitted shade and horticultural products in conjunction with its Indonesian manufacturing partner P.T. Carillon Sdn Bhd, which were sold internationally, including the USA, New Zealand and the Middle East. The Nolan Group had been distributing these products in Australia for many years.

The original merger and subsequent acquisitions have allowed the company to realise its ambition to become a complete wholesaler of outdoor textiles and related products to the automotive, marine, awning and blind, industrial fabrics and commercial market sectors. The business trades from six branches throughout Australia, located concentrically with its customer base and the country's population; and has contract arrangements with Polyfab operations in the USA and the Middle East.

The Sydney Warehouse in the mid-sixties. Captured in the picture (bottom right) is William Marden Nolan, son of Nolan O'Rourke's founder William Bernard Nolan.

Our Company's philosophy is building and strengthening partnerships with our Customers and Suppliers. Our team of account managers and customer service staff undertake extensive product and sales training to ensure they provide the highest level of support and advice possible.



Thomas Peacock and Sons factory at Maylands, Perth circa 1946.

Got You Covered.
Polycotton Canvas; Coated or Laminated Industrial and Architectural Fabrics
Technical Manual number Five

INTRODUCTION 1
- What are Coated or Laminated Industrial fabrics? 1
- Fabricator Obligations under Consumer Law in Australia 1
- The objectives of this guide 1
- Types of Industrial and Architectural Fabrics 3
- Product Dimensions, Packaging and Labelling 3

PRODUCT CHARACTERISTICS 11
- The characteristics of polycotton canvas 11
- The Characteristics of Reinforced PVC Fabric 12
  - Polyester scrim 12
  - Types of Plasticisers 14
  - The importance of surface lacquers 16
- The Characteristics of Coated Polyolefins 17

FABRICATION AND USAGE (INDUSTRIAL APPLICATIONS) 18
- Factors to consider in product selection 18
- Unusual Applications 18
- General Fabrication and Performance Issues 19
  - Dimensional Change 19
  - Tear 20
  - Mould and Mildew 21
  - Flex Cracking and Delamination 21
  - Water Penetration Resistance 23
- Fabricating Canvas 23
- Fabricating Polyolefins 24
  - Welding 24
  - Repairs to damaged tarpaulins 24
  - Installing dam liners 25
  - Grain storage 25
  - Greenhouses 25
- Fabricating Coated PVC 26
  - Colour variation and opacity 26
  - Welding 26
  - Seam Sealing 26

FABRICATION AND USAGE (ARCHITECTURAL APPLICATIONS) 27
Architectural Design 27
The European Classification of Coated PVC Fabrics by 'Type' 29
Structural Project Tolerances 30
Pre-Stress 31
Derivation of Elastic Parameters 32
Interpreting Biaxial Test Results 32
PRINTING AND PAINTING 36
Surface and Ink compatibility 36
Screen Printing 38
Wind Load on Banners – "A Hole Lot Better?" 38
GENERAL CLEANING AND CARE 40
Resistance to chemicals found in common cleaners 40
Polycotton Canvas 40
PVC coated or laminated polyester 42
Coated Polyolefins 42
DETAILED PRODUCT SPECIFICATIONS 42
Physical Properties 42
SUSTAINABILITY, ENVIRONMENTAL IMPACT AND RECYCLING 43
Molecular Structure of Base Materials 43
PVC Coated Polyesters 51
Polycotton Canvas 52
Coated Polyolefins 52
GLOSSARY OF TECHNICAL TERMS 53
Appendix A DESIGN OF ON FARM GRAIN STORAGES 56
Appendix B – WELD FAULT FINDING CHART 60
Appendix C - NOLAN GROUP PRODUCT WARRANTIES 62
C 1 Polycotton Canvas 62
C 3 PVC Coated Polyester Fabrics (Architectural) 64
Appendix D – CHEMICAL RESISTANCE OF COATED FABRICS AT 20^{o} CELSIUS* 65

Disclaimer

INTRODUCTION

What are Coated or Laminated Industrial fabrics?

The term “Industrial Fabrics” is used to describe those fabrics used in outdoor applications, such as tarpaulins and covers. “Coated” refers to a method of stabilising and waterproofing the base fabric, by application of the coating compound in liquid or molten form, usually on both sides. The objective of “Lamination” is the same, but the water proofing medium is applied as a thin solid film.

Polyolefins are used as both the base yarn and the coating of a number of woven outdoor fabrics imported by The Nolan Group, that are used as light-weight covers for a host of agricultural and industrial applications, including grain covers; roofing and walling for greenhouses and animal shelters; dam liners; tarpaulins; and cricket pitch and similar sports covers.

PVC, short for Polyvinyl Chloride, is used as coating medium or film for many types of fabrics, but particularly woven polyester. The combination provides a durable and tough composite material, used for truck side curtains, tarpaulins, marquees, tents and banners. The same type of composite material, but with a different lacquer finish, is also used for lightweight tension structures.

PVC coated mesh, the grid of which is also polyester, is used as privacy and insect screens, windbreaks, and as a shading material.

Polycotton Canvas is included in this guide because it is widely used by the same fabricators who manufacture products from the synthetic fabrics described above.

Fabricator Obligations under Consumer Law in Australia

Under the Australian Consumer Law (which was enacted January 2011), a Textile Fabricator, being ‘a supplier and manufacturer of goods’, must guarantee that his goods are of ‘acceptable quality’. The test for ‘acceptable quality’ is whether a reasonable consumer would find them fit for purpose, acceptable in appearance and finish, free from defects, and durable, that is, function for a reasonable period of time after purchase.

A “consumer” can be a corporation. For example, a building body corporate, which commissions a fabricator to undertake work up to $40,000 in value, is considered a ‘consumer’ under the Act, and has considerable rights of remedy if the goods are found not to be of acceptable quality, including full replacement or refund.

To assist fabricators in managing this risk, the Nolan Group has developed a formal ‘Fit for Purpose’ statement which is designed to clarify the meaning of the frequently used terms of the Consumer Act, in the context of products used in an outdoor environment. This refers to the basic product technical specifications published in our “Fabricator Product Catalogue” and Technical Guides and is incorporated into our formal warranties.

The objectives of this guide

It is important that textile fabricators have an in depth understanding of the materials used in their trade. This is because essential features of products used in the industry are not easily discerned. For example, fabrics may have UV stabilisers, flame retardants and mildew inhibitors added, but none of these features can be determined simply by sight or feel. It is therefore important to understand the production processes, specifications and test methods that are used to assess comparative performance. Only then can an informed choice be made of the right product to use in a particular circumstance, or between competing products.

Many of products described in this guide are used in other applications, such as large fabric structures and marine canopies. Because of this commonality, the basic features of product composition and manufacture, together with a description of the fabric tests that underpin the technical specifications of the products, are contained Technical Guide Number One “How to Tell a Good Yarn – Textile Manufacture and Testing”.

The basic objective of this guide is to collate and present the technical information that is specific to the Industrial Fabrics and Architectural sectors. In particular, it provides advice on product selection and fabrication, based on industry experience gleaned from a wide range of end-use applications. The products supplied by The Nolan Group are sourced from quality endorsed manufacturers, and their quality control procedures are fully documented and externally audited. This is designed to ensure that the products when manufactured do meet the published specifications. Further, the Nolan Group’s limited warranties are supported by those offered in turn by our respective manufacturers, which should give confidence that the products supplied will indeed meet our “Fit for Purpose Statement”

THE NOLAN PROMISE

The Nolan Group ‘Fit for Purpose’ Statement

The Nolan Group’s products are specifically designed to be used for the recommended purpose and are guaranteed to be supplied free of defects.

‘Free of Defects’ means that the product meets its published description and technical specification and is homogeneous in appearance after allowance for minor variance , such as weaving faults, that are inherently the result of the manufacturing process, and accepted as industry standard.

The Nolan Group further warrants that the product will perform satisfactorily when used in its design context in the temperate climatic conditions experienced throughout Australia.

‘Satisfactorily’ means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and weathering, such as colour variation, strength loss, and dimensional change. Extreme climatic conditions, particularly high temperature and humidity may accelerate the inevitable product degradation.

‘Expected Life’ is at least the period covered by warranty, provided the product is installed properly, and cleaned and maintained as recommended.

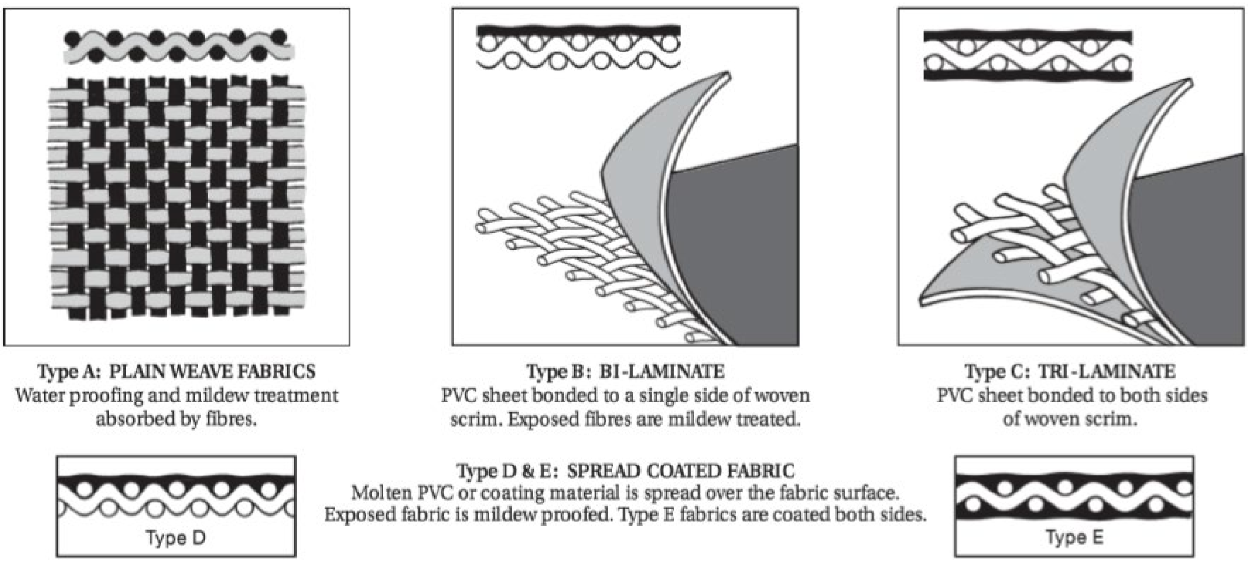
Types of Industrial and Architectural Fabrics

There are many brands of Industrial and Architectural fabrics available on the market, of varied composition, weather-proofing, weights and widths. But all of them can be classified into five basic groups, as illustrated in **Figure One** "Physical Structure of Outdoor Fabrics". The industrial Fabrics supplied by The Nolan Group, are grouped into these categories in all the company's "Technical Guides" and "Fabricator Catalogue".

Polycotton Canvas falls into the Type A "Plain Weave Fabrics" classification. The Nolan Group's canvas products are manufactured by either Wax Convertor Textiles (WCT) or Bradmill, and marketed under those company names.

Most of the other Industrial Fabrics fall into the Type C or Type E categories. The Herculite branded (Type C) products are manufactured by Herculite Products Inc of the USA. The remaining Industrial Coated Fabrics (Type E) are manufactured under contract to the Nolan Group's specifications by various SE Asian suppliers. The Architectural Fabrics (also Type E) are manufactured by the Sattler Group in Europe. A description of the products' composition, features and applications are listed in **Tables One (a)** to **(g).**

FIGURE ONE- "Physical Structure of Outdoor Fabrics"



Product Dimensions, Packaging and Labelling

The Nolan Group's Industrial Fabrics are produced in roll form. The products are wrapped around a cardboard core, and some are wrapped either in heavy duty paper or plastic. Regardless of the packaging, all products are labelled on at least one end at the factory and show, at a minimum, a description as well as the factory batch and part numbers; and details of the range, such as colour, width, and roll length.

The Nolan Group has its own barcoding system. Upon delivery to the warehouse, each roll is bar-coded (**Figure Two (a**)), which is the linkage to the original Nolan Group Order number, and all other records in the supply chain. The "date of last transaction" may be for example, when the container was received, or the roll itself receipted into a particular warehouse. When the roll or a cut length is sold to a fabricator, a label is attached to the parcel, which is also bar-coded. (**Figure Two (b)**), and referenced on the delivery docket and invoice; and linked to the customer order number. Thus, the origin of the material can be traced from any of these records, enabling for example, delivery of additional material from the same batch, should this be required.

Figure two (a) – Typical Roll Barcode Label

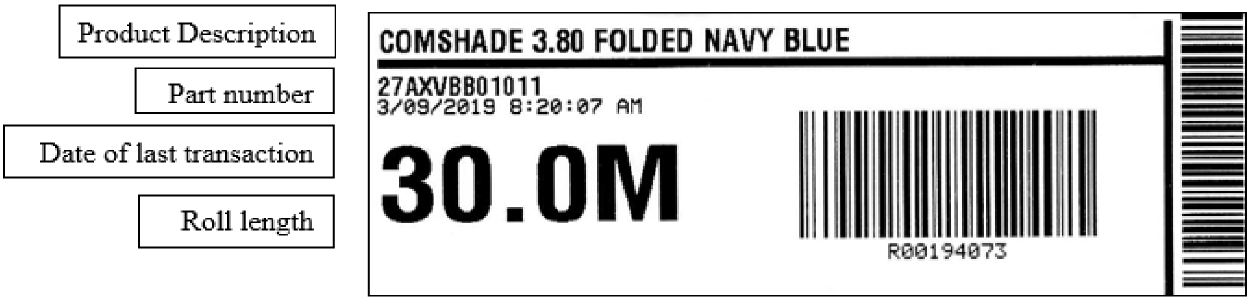
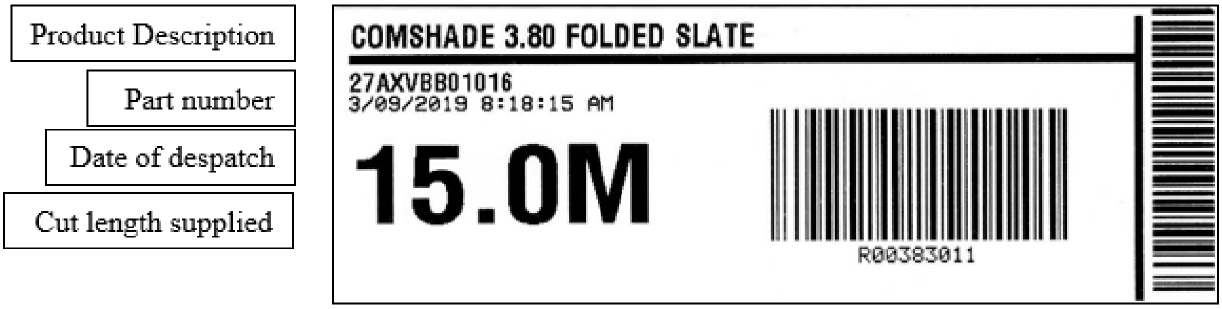


Figure Two (b) – Typical Cut length Bar Code Label



Freight companies charge both by weight and cubic volume, but generally the products are too heavy for the "cubic" formula to apply. For convenience the relevant roll widths and weights are tabulated in **Table One.** These values can be used to calculate total pallet loads, and checked against the Safe Working Load of forklifts or the pallet racking in which they are stored.

A truck side-curtain fabricated from the Nolan ProTEX range of coated PVC

Table One (a) – “Type A” Polycotton Canvas manufactured by Wax Convertors Textiles (WCT)

<table>
<tr><th>Brand Name</th><th>Nominal finished weight</th><th>Width</th><th>Roll Weight</th><th>Description
(All rolls 50 m in length)</th><th>Features and recommended applications</th></tr>
<tr><td>Coolabah</td><td>275 gsm (finished)
6 oz/yd^2 (loomstate)</td><td>204 cm</td><td>28 kg</td><td rowspan="2">Polyester /cotton ratio 65/35, Warden proofed for mildew, rot and water penetration resistance.</td><td>Lightweight product suited for applications where a large amount of fabric needs to be folded into a compact area. .e..g tents, roofing and walling, campervans</td></tr>
<tr><td>Billabong</td><td>370 gsm (finished)
9 oz/yd^2 (loomstate)</td><td>204 cm</td><td>38 kg</td><td>Medium Weight product design for tents, annexes and Campervans, and general purpose covers</td></tr>
<tr><td>Basecamp</td><td rowspan="2">505 gsm (finished)
12 oz/yd^2 (loomstate)</td><td>200 cm</td><td>52 kg</td><td rowspan="2">Polyester /cotton ratio 52/48, Warden proofed for mildew, rot and water penetration resistance.</td><td rowspan="2">Heavy weight product suited foe swags, tarpaulins, trailer covers, annexe roofs, marquees</td></tr>
<tr><td>DX 12</td><td>204cm</td><td>51 kg</td></tr>
<tr><td>Bullduck TT</td><td>535 gsm (finished)
12 oz/yd^2 (loomstate)</td><td>204 cm</td><td>55 kg</td><td>Polyester /cotton ratio 50/50, Reinforced with ‘tearstop’ yarns in both directions. Warden proofed for mildew, rot and water penetration resistance.</td><td rowspan="2">Heaviest products available. Suited for heavy duty truck tarpaulins and trailer covers</td></tr>
<tr><td>CS 12 TS</td><td>575 gsm (finished)
13 oz/yd^2 (loomstate)</td><td>204 cm</td><td>59 kg</td><td>Polyester /cotton ratio 52/48, Reinforced with ‘tearstop’ yarns in both directions. Warden proofed for mildew, rot and water penetration resistance.</td></tr>
</table>

Table One (b) – "Type A" Polycotton Canvas manufactured by Bradmill Textiles

Brand Name	Nominal finished weight	Roll Length	Roll weight	Description (All products 200cm in width)	Features and recommended applications
300 Superdux	345 gsm (finished) 8 oz/yd^2 (loomstate)	50 m	35 kg	Polyester /cotton ratio 65/35, Warden proofed for mildew, rot and water penetration resistance.	Medium Weight product design for tents, annexes and Campervans, and general purpose covers
373 Superdux	515 gsm (finished) 12 oz/yd^2 (loomstate)	50 m	52 kg	Polyester /cotton ratio 52/48, Warden proofed for mildew, rot and water penetration resistance.	Heavy weight product suited foe swags, tarpaulins, trailer covers, annexe roofs, marquees
440 Superstop	530 gsm (finished) 12 oz/yd^2 (loomstate)	55 m	58 kg	Polyester /cotton ratio 52/48, Reinforced with 'tearstop' yarns in both directions Warden proofed for mildew, rot and water penetration resistance.	Heaviest products available.. Suited for heavy duty truck tarpaulins and trailer covers
411 Kordux	530 gsm (finished) 14 oz/yd^2 (loomstate)				

**Note: Products not sold in Western Australia*

Table One (c) – "Type C" Herculite PVC laminated Polyester Fabrics

Brand Name	Nominal finished weight	Width	Roll weight	Description	Features and recommended applications
Herculite 80 grade	655 gsm	152 cm	46 kg	PVC tri-laminate, 100% polyester Plain weave scrim. Acrylic lacquer both sides.	Waterproof, High tear strength, mildew resistant, and easy to clean. Suited as general purpose heavy duty cover, particularly in a tropical climate. Meets the Navy MilSpec.
Herculite 2000	605 gsm	200 cm	28 kg	PVC tri-laminate, 100% polyester weft insertion scrim. Acrylic lacquer both sides.	

Table One (d) – "Type E" Nolan Group ProTEX PVC Coated Polyester Fabrics

Brand Name	Nominal finished weight	Width	Roll Length	Roll weight	Description	Features and recommended applications
"PT Extra"	500 gsm	250 cm	30 m	38 kg	PVC coated, 100% polyester plain weave scrim. Acrylic lacquer both sides.	Waterproof, mildew resistant, and easy to clean. High Surface adhesion, and easily welded, Suited as general purpose lighter weight cover, or Tarpaulin. Specifications meet the "Medium Duty" classification of AS 2930-1987 "Textiles – Coated Fabrics for Tarpaulins"
Spanlite	537 gsm	250 cm	50 m	67 kg		
ProTEX GP	680 gsm	250 cm 320 cm	30 m	51 kg 65 kg	Description as above.	Features as above. Specifications meet the "Heavy Duty" classification of AS 2930-1987 "Textiles – Coated Fabrics for Tarpaulins". Suited for marquees, awnings, canopies, covers, tarpaulins, and long road haulage.
Toughstuff	610 gsm	205 cm	30 m	38 kg		
ProTEX TS	680 gsm	250cm	30 m	51 kg	PVC coated, 100% polyester tearstop weave scrim. Acrylic lacquer both sides.	
ProTEX ETS	680 gsm	320 cm	30 m	65 kg	Specification as for ProTEX TS.	
Sidecurtain	900 gsm	250 cm	30 m 200 m	69 kg 450 kg	PVC coated, 100% polyester Panama Weave scrim. Acrylic lacquer both sides.	
ProTEX ETS "FRAS"	680 gsm	250 cm	30 m	51 kg	Physical Specification the same as ProTEX ETS, but enhanced Fire Retardant and Anti-static properties.	Specification meets the NSW Government Mine Safety Guideline MDG 3608 for "Non-metallic materials for use underground coal mines"
Elva-Block	950 gsm	200 cm	100 m	190 kg	Especially formulated oil and fuel resistant PVC coated, 100% Polyester heavy duty plain weave scrim.	Chemical spill control, including bunding and capping, non-potable water tank lining, and chemical resistant covers.

Table One (e) – "Type E" Sattler PVC Coated Polyester Fabrics

Brand	Nominal finished weight	Nominal Width	Roll Length	Roll Weight	Description	Recommended applications
Polyplan						
680	670 gsm	250 cm	65 m	110 kg	Plain Weave, 1100 Dtex high tenacity polyester scrim, with same yarn count in each direction. Acrylic lacquer both sides.	Light weight Architectural fabrics designed for small shade structures and fixed wind rated umbrellas
680 BO	780 gsm	250 cm		128 kg	Construction as for 680 but with Block -Out coating	
680 LW	670 gsm	250 cm		110 kg	Construction as for 680 but with low wicking yarn.	
745	640 gsm	300 cm		125 kg	Similar construction to 680 but Matt finish	
787	780 gsm	300 cm		152 kg	Similar construction to 680 BO but Matt finish	
Candy	690 gsm	300 cm		135 kg	Similar construction to 680 but Translucent	
Atlas						
Type 1	700 gsm	250 cm	65 m	114 kg	PVC Coated, high tenacity, anti-wicking polyester scrim, with a patented "Atlas" weave designed to promote similar elastic behaviour in the warp and weft directions.	All tensile structure applications. Fabrics meet the specifications of the European Design Code.
Type 2	900 gsm			146 kg		
Type 3	1200 gsm				Incorporates a weldable PVDF lacquer (TFL) or a pure PVDF lacquer (TFX) both with Titanium Dioxide protective finish.	
Type 4	1350 gsm					
Type 5	1550 gsm					

Table One (f) – “Type A” Coated Polyolefins

Brand Name	Nominal finished weight	Width	Roll Length	Roll Weight	Description	Features and recommended applications
Polyfab Solarpro	180 gsm	183 cm 205 cm 270 cm	50 m, 100 m, 1000 m 50 m, 100 m, 1000 m 50 m, 100 m, 1000 m	16 kg, 33 kg, 329 kg 18 kg, 37 kg , 369 kg 24 kg, 49 kg, 486 kg	10 x 10 x 1100 denier tapes LDPE coated both sides (thickness 45 microns).	Lightweight Cover Suited for Agricultural and Horticultural Applications
Polyfab Polyshield	250 gsm	205 cm	50 m, 1000 m	26 kg, 513 kg	12 x 12 x 1100 denier tapes LDPE coated both sides (thickness 55 microns).	General purpose rural, camping and industrial e.g. haystack covers, tent flooring, emergency tarps
Flexicover	350 gsm	205 cm	1000 m	718 kg	100% Polypropylene, plain weave coated both sides.	Large size tarpaulins, grain covers, dam liners.

Table One (g) – “Type E” PVC Coated Polyester Mesh (“Meshtex” brand)

Brand Name	Nominal finished weight	Width	Roll Length	Roll Weight	Construction (‘pic’ count per inch)	Features and recommended applications
Micro	140 gsm	189 cm	50 m	13 kg	PVC coated polyester 24 x 24 x 250 denier.	Suited for windows in fixed and roll-up awnings, doors and privacy screens.
Maxi	180 gsm	189 cm	50 m	17 kg	PVC coated polyester 16 x 16 x 420 denier.	
Breeze	420 gsm	200 cm	50 m	42 kg	PVC coated polyester 16 x 12 x 1000 denier.	Outdoor furniture and Marine
Cover	420 gsm	250cm	50 m	53 kg	PVC coated polyester 15 x 15 x 1000 denier.	Covers, screening and general purpose
401	440gsm	189 cm	52 m	43 kg	PVC coated polyester 27 x 30 x 250 denier.	Heavy duty screening material
Truck	320gsm	300 cm	50 m	48 kg	PVC coated polyester 13 x 9 x 1000 denier.	Permeable covers for haulage trucks and trailers

PRODUCT CHARACTERISTICS

The characteristics of polycotton canvas

Polycotton canvas is woven from a blend of cotton and polyester yarns, and stabilised by heat treatment after weaving. It is made highly water resistant by the deposition of a hydrophobic compound, which also incorporates fungicides, onto the fabric surface. (Refer Technical Guide Number One for a detailed outline of the process) Unlike polyester, cotton is a highly absorbent material, and is particularly amenable to this treatment. Polyester, on the other hand has much better tensile properties than cotton, and its addition to the product substantially improves the fabric's strength to weight ratio.

The product has been widely used as tenting and tarpaulin material for decades, and has proven performance. Its primary advantage is its 'breathability', which allows the movement of air through the fabric, at the same time as its surface 'proofing' prevents water penetration. The combination can be particularly important in an enclosed outdoor environment, such as camper annexes, where internal temperature and condensation need to be controlled.

During the weaving process, the warp yarns are held in tension, whereas the weft yarns are not, being simply inserted between alternate warp yarns. This difference in tension causes different behaviour of the canvas in each direction. The (approximately) straight warp yarns simply stretch under load, whereas the bent fill yarns flatten. Hence tensile strength and elongation are different in each direction.

The higher tension applied to the warp yarn also results in greater shrinkage in this direction, as the yarns tend to contract once residual stresses incurred during manufacture are relieved. Shrinkage is also caused by moisture absorption during weathering. When wet, yarns swell, causing them to contract in length in the woven matrix and therefore the fabric overall to shrink. The action of heat can have a similar effect. Due to its hydrophilic propensity, cotton shrinks more than synthetic yarn when wetted.

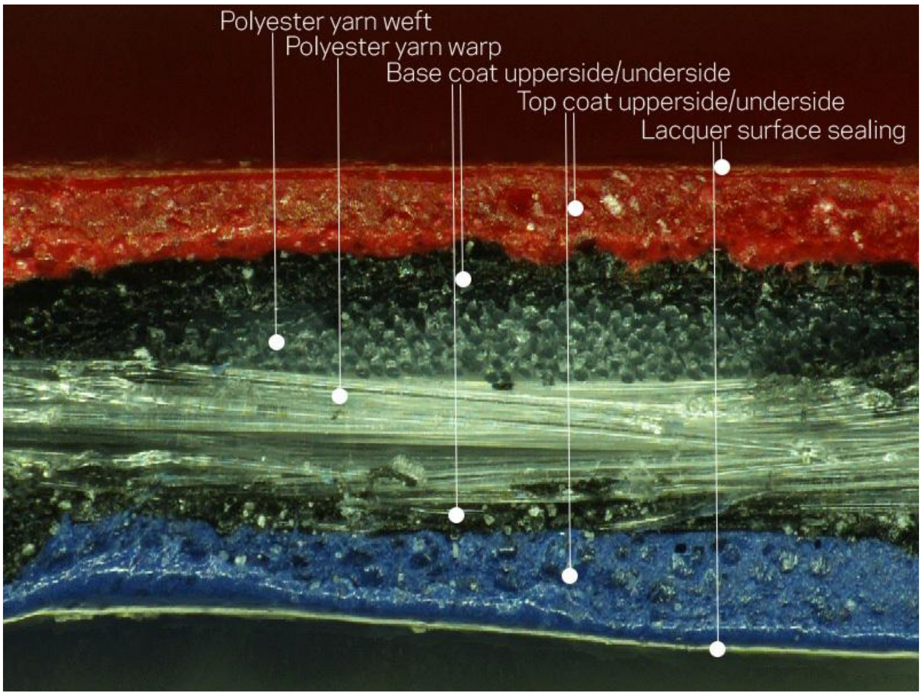
A camping tent fabricated from WCT Polycotton canvas

The Characteristics of Reinforced PVC Fabric

Reinforced PVC is a composite product, comprising a base woven scrim overlaid by one or more flexible vinyl films, applied through either lamination or coating, and in turn lacquered with a protective finish. The woven scrim provides tensile and tear strength, and resistance to dimensional change; whereas the vinyl films provide waterproofing, abrasion and chemical resistance, which are further enhanced by the protective lacquer. The typical construction of a PVC Coated Fabric is illustrated in **Figure Three.**

Within this broad description, there are many different types of product, some formulated to meet a specific requirement. For example, some fabrics have a very flat scrim, polished surface and applied finish to enhance paint or ink receptivity. Fabrics designed for extended outdoor use have high levels of UV inhibitor added to the fabric and sometimes water-repellent and fungicidal compounds incorporated into the yarn of the scrim.

Figure Three – The Typical cross-section of a PVC Coated Fabric (magnification 50x)



Polyester scrim

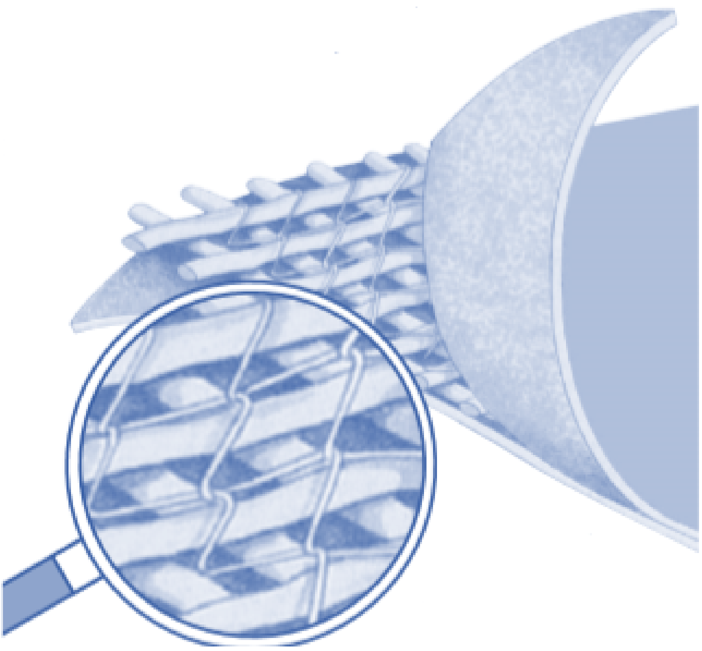
In coated and laminated PVC fabrics, the basic building block of the scrim is the polyester filament fibre, which is twisted slightly to increase its tensile strength (to form a fibre of "high tenacity"). High tenacity polyester fibre is very stable, and relative to other types of synthetic fibres, has many desirable characteristics, such as good chemical resistance, low moisture regain (0.4%), good elastic recovery, and reasonable tensile strength. The raw fibres are vulnerable to UV degradation, losing up to 50% of their initial tensile strength over time, but are protected by UV inhibitors in the PVC film.

A number of filaments are combined into a composite yarn, either laid loosely in parallel, or twisted together. Once the yarns are made they are formed into a base fabric, either by weaving (usually a "Plain Weave"), or simply by being laid one across the other, and knitted together with a third yarn ("weft insertion"), as shown in **Figure Four.**

The tightness of weave influences the characteristics of a laminated end-product. A loosely woven scrim allows a high adhesion to be developed with the compatible films on either side of the scrim. It has high tear strength, because the looseness allows "bunching" of the yarns under the action of tearing, but relatively low tensile strength because there aren't many of them. On the other hand, a tightly woven scrim has a high tensile strength, but relatively low tear strength for exactly the opposite reason. The films on a tightly woven scrim rely entirely on the mechanical or chemical bond with the scrim itself.

As with canvas, the different relative yarn tension in the warp and weft direction means that the tear and tensile behaviour is also different, with the extension under loading much more pronounced in the weft than the warp for "Plain Weave" scrim.

Figure Four – Schematic view of a "Weft Insertion" Scrim.



The terminology of "warp" and "weft" is also used to describe weft insertion scrims, but because the yarns deform the same way (by simply stretching), the ultimate load and elongation characteristics are similar in each direction.

A weft insertion scrim tends to have lower tear and tensile strengths relative to a plain weave of the same yarn composition. They are however much flatter, since the overall thickness approximates two layers of yarn, compared to three in a woven fabric. This results in a smoother finish of the PVC film, which is particularly important when printing of the surface is envisaged.

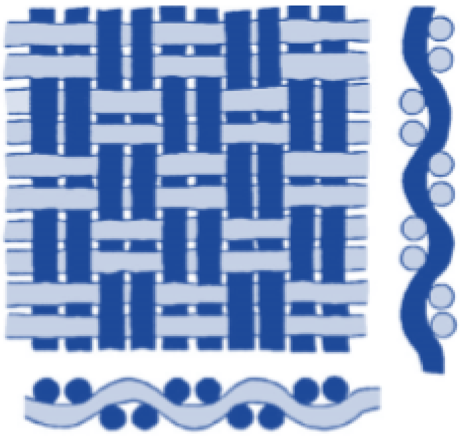
Most scrims in coated fabrics have a basic one to one ratio of yarns in the warp and weft directions, but ProTEX "Side-Curtain" has a two by two 'Panama weave'; and ProTEX TS and ETS have a 'Tearstop weave', as shown in **Figures Five (a) and (b)** respectively. Both structures significantly increase tear strength, relative to a plain weave of the same weight, but the doubling up of a heavier denier yarn in the 'Tearstop' results in a bulge in the coating **Figure Five (C)**, which affects the appearance, print receptiveness and possibly abrasion resistance.

The scrim of the Atlas Architectural fabrics (**Figure Five (d)**) is designed to minimise the extent of crimpimg of the weft yarns by only inserting them between every fifth warp yarn. As previously mentioned, crimping is the pricinple reason why the strain response in the weft direction is different to that of the warp. Because of reduced crimping, the Atlas weave results in the fabric being more isotropic than a similarly constituted fabric with a plain weave.

Isotropy is a desirable characteristic of architectural fabrics, because the strain response to applied load is the same in each direction.

Figure Five – Types of scrim used in Coated PVC Polyesters

(a) Panama Weave



(b) "Tear-stop" weave

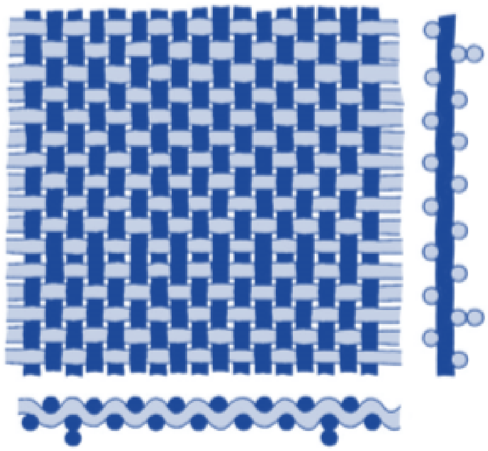


Figure Five (c) – Bulge in the PVC coating resulting from a "Tear-stop" weave

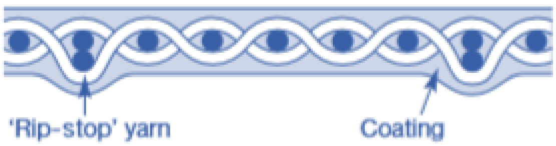
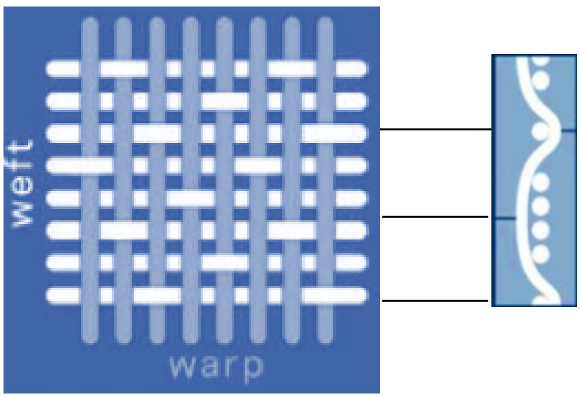


Figure Five (d) Detail of the "Atlas" Weave



Types of Plasticisers

There are different types of plasticisers, which are generally esters, but phthalates are by far the most commonly used plasticisers in flexible PVC .Phthalates have generated significant negative publicity, because of health concerns, which is not justified for every type, and some discussion of the whole family is warranted to clarify the situation.

There are many types of phthalates, which are esters reacted from phthalic acid. They have similar molecular structure comprising hydrocarbon chains incorporating aromatic rings and oxygen. The difference between the various types is essentially the result of a differing length and format of the hydrocarbon chain. The most commonly used with coated PVC fabrics, because of their very good compatibility with the PVC polymer, has been DEHP (Di-ethyhexyl phthalate), also known as DOP, and DIOP (Di-iso-octyl phthalate). The historical widespread use of DEHP is the result of its all-round plasticising performance, which has provided acceptable properties for a vast amount of cost-effective, general purpose products.

However, some concerns have been raised repeatedly as to the potential health effects of these types of phthalates if ingested, even though recent assessments have argued cogently that the exposure of DEHP to the general public is of little risk. Despite this, DEHP, under a REACH directive of February 2011, has been phased out by the European Union. REACH is an acronym for the European Community regulation of chemicals and their safe use, namely the **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances.

The DEHP issue is not particularly relevant to our industry's coated PVC's, because the concerns are based on direct ingestion of significant concentrations of the Phthalate. Further, in an outdoor situation, the plasticisers when leached are subject to rapid biodegradation, and do not persist in the environment.

Nonetheless, because of the REACH restriction, the European market has been shifting in the last decade to other heavier phthalates of proven safety, i.e. DINP (Diisononyl phthalate), DIDP (Diisodecyl Phalate), and DPHP (Di 2-Propyl Heptyl Phalate) which today represent over 70% of all the phthalates currently being produced. They have all been registered for REACH and do not require any classification for health or environmental effects.

ProTEX GP and Achilles Rollclear used in a temporay framed tent structure

The importance of surface lacquers

From a life cycle perspective, the main risk to Industrial and Architectural Fabrics is degradation due to Ultra-violet light, which attacks plasticisers and undermines the integrity of the polyester scrim. Without protection, the fabric loses strength over time, and becomes brittle, as plasticiser migrates to the surface, which becomes sticky, attracting a residue of dirt that is impossible to clean off.

For this reason, surface lacquers play a crucial role in extending the life of the fabric. They are designed to protect and insulate the PVC coating from the damaging UV radiation and to improve cleanability. There are basically four types of lacquer finishes; acrylic, PVDF, an acrylic PVDF blend, and Titanium Dioxide (TiO_2). Each finish has varying degrees of effectiveness and weldability. The lacquers are all thin coatings of less than twenty microns.

Acrylic is the most commonly used lacquer for general purpose coated PVC's. It is economical, resistant to chemical attack, and substantially improves the fabrics appearance. A pure PVDF (polyvinylidene fluoride) lacquer is a stable and proven performer. It has a high resistance to chemical attack, Ultra-Violet and gamma radiation; and has excellent mechanical properties in tension and deflection. However, PVDF lacquered fabrics cannot be welded together without physically removing the coating at the joins, which results in fractured protection. A blend of acrylic and PVDF (known as "weldable PVDF") solves this problem, but at the expense of performance, which is reflected in the duration of the warranty offered.

An inflatable structure manuafctured fron Protex ETS forms the boundary of a mini-soccer field

The addition of TiO_2 into a weldable PVDF lacquer is a relatively new innovation, and is included in both the TFX and TFL lacquers on the Atlas ranges. The compound TiO_2 has a high refractive index, strong UV light absorbing capabilities and resistance to discolouration. For this reason it is widely used as the principal component of sunscreens. Research has shown that when combined with nitrogen ions, TiO_2 acts as a photo catalyst when exposed to light, and has strong oxidative decomposition powers, and for this reason is added to paints and other external products to enhance sterilising and deodorising properties. Again under the action of Ultraviolet light, TiO_2 is super hydrophilic, and is used as a coating on glass to enhance anti-fogging and self-cleaning characteristics.

To exhibit these various properties, TiO_2 must be supported on a suitable reactive substrate, which is generally proprietary knowledge, and therefore it is uncertain whether all these desirable properties can be exhibited at the same time. However, when introduced into a lacquer mix, at the very least it acts as a very effective shield to the otherwise harmful effects of Ultraviolet light, and may also facilitate oxidising of surface pollutants; and induce some self-cleaning effects.

The Characteristics of Coated Polyolefins

There are two different types of yarn used in the manufacture of coated polyolefin fabrics – flat tape (Solarpro and Polyshield) and multifilament (Flexi-cover).Weaving of Polyolefin fabrics follows the same process as other “Plain Weave” textiles, but is complicated when tape yarns are woven. These can be twisted and buckled in the loom, which makes production of a perfectly smooth and homogeneous surface in these types of fabrics virtually impossible.

Coating is applied by extrusion and is generally less than 70 microns (0.07mm) in thickness, but represents about half the weight of the finished fabric. It also makes the fabric stiffer and reduces its raw tear strength. Generally, adhesion, weldability, and water resistance are directly related to coating thickness, although the quality of the resin used is also significant. Because the coating applied has the same chemical composition as the internal scrim, the finished fabrics are homogeneous. This is an advantage in a recycling process, as no separation of the scrim from the coating is required, which is the case with PVC coated polyester. The inclusion of colour pigments and UV stabilisers alters the intrinsic chemical resistance of the polyolefins. For example, UV stabiliser is attacked by halogens (e.g Chlorine, Bromine), sulphur, and concentrated acids.

There are intrinsic similarities between polyethylene and polypropylene. Apart from very similar inherent tensile strength, both are chemically inert and do not absorb water. They have good abrasion resistance, uniform elastic properties, and are lighter than water. They both have similar flammability behaviour and rely heavily on added inhibitors for UV stability.

Although both are largely unreactive chemically, the presence of the CH_3 (methyl) group in polypropylene makes it slightly more susceptible than polyethylene to attack by strong oxidising agents. Its relative advantages are its greater flex crack resistance and its higher temperature resistance, which means it is more amenable to annealing (and therefore tensile strength enhancement) during yarn production.

Protex PT XTRA used in a wheeled, frame mounted cricket pitch cover

FABRICATION AND USAGE (INDUSTRIAL APPLICATIONS)

Factors to consider in product selection

In selecting a fabric, the first point to be considered is the weight per square metre. This is particularly important for tarpaulins or covers that are frequently taken on and off, as a large one can be heavy to handle, and awkwardly bulky to fold. Weight per se is not necessarily an appropriate indicator of strength, and the ratio of strength to weight is a better one for comparative assessment.

The whole point of a tarpaulin, tent, annexe or a cover is to provide protection, particularly from water penetration. However, there is a trade-off between this and breathability, and where the latter is important, polycotton canvas is the only logical choice, unless mechanical vents are incorporated into the design.

The fact that canvas retains a high level of water vapour permeability allows spaces that are fully enclosed to match the external ambient atmospheric humidity, thus preventing internal condensation, an important factor in reducing mildew risk. However, the proofing compounds that provide water penetration resistance are not permanent, and wear off over time; but the fabricated product can be re-proofed relatively easily.

Coated polyolefins are the lightest fabrics available. The main advantages of a coated polyolefin over a coated or laminated PVC are its higher strength to weight ratio, better chemical resistance, easier cleanability, and of course, recycling potential. PVC coated polyester contains plasticiser, which can migrate to the surface causing it over time to become tacky,and attract dirt particles. Containing no plasticiser, coated Polyolefins do not exhibit this problem. Because UV stabiliser is contained in both the base yarn and the coating, they also tend to last longer and have relatively lower strength loss, retaining more than 80% of their initial strength after three years.

The main advantages of PVC coated polyester over Coated polyolefins are its good flex cracking and abrasion resistance, and shear brute strength, which why it is predominantly used in transport, marquees and lightweight structures. It is easily fabricated, RF welded (polyolefins can only be wedge or hot air welded), and can take brutal field punishment. It is inherently more receptive than polyolefins to painting or printing, and has a reasonable expected life.

“Flexicover”, whilst similar in appearance to a PVC coated polyester, is a coated polypropylene. It has break and tear strengths equivalent to one of twice its weight. It is comparatively “self-cleaning”, and a much better insulator, an advantage for its use in tents and animal shelters. Its relative disadvantages are lower abrasion resistance, and a tendency of the multifilament yarn in the scrim to wick. The risk of unsightly mildewing in this context is ameliorated by the use of black filaments.

Unusual Applications

PVC is not inert, and although it has good overall chemical resistance (refer **APPENDIX D**), generic reinforced PVC cannot be used in every application. Examples where special products or coatings are needed are abattoir curtains, fish tank liners, and oil booms.

Elva-Block is technical membrane fabric with an encapsulated and sealed edge. It is especially designed for liquid containment and control, and has exceptional resistance to oil, fuel and chemicals that would otherwise attack the other types of PVC.

The physical environment, particularly in building construction and mining applications is also important. For example, fabric used to manufacture chutes for containing construction debris will be subject to high abrasion, and cannot be expected to have an extended life. Similarly, concrete curing blankets, unless carefully sealed along the edges, can be affected by high pressure steam.

ProTEX ETS (FRAS) is a Fire Retardant and Anti-Static product designed to meet the NSW Government Mine Safety Guideline MDG 3608 for “Non-metallic materials for use in underground coal mines”. This standard is often referenced in other parts of the mining industry.

Herculite manufacture reinforced laminates for speciality purposes. These are of similar construction to the general industrial range, but with additives to the vinyl or adhesive that make them bacteria resistant, stain resistant, and anti-static. “Surechek” branded fabrics are not UV stabilised and are designed for indoor use only, and are marketed mainly to the medical industry. Nonetheless, they may be functional for use in other applications, such as food processing (Sure.Chek 44 XL), fire blankets (Sure.Chek FFB), and low-static computer covers (Sure.Chek Lectrolite).

General Fabrication and Performance Issues

Once the choice of fabric has been made, it must then be converted into a finished product, which requires patterning, cutting out, joining panels, and edge sealing. Regardless of the fabric selected, allowance must be made for its potential dimensional change, and the possibility of slight colour and opacity variation between rolls. With any fabric, a sensible precaution to avoid problems is to fabricate the finished product from the same roll, or for large projects, the same batch.

Dimensional Change

Dimensional change may be the result of:-

- relaxation of the stresses applied during the process of manufacture, or reaction to changes in moisture content and temperature (e.g. Shrinkage);
- forces applied to the finished product (e.g. torque applied by an electric motor or winch)
- creep, which is a time dependent increase in strain exhibited by a material under a constant load. In general industrial applications, the effect of creep can be ignored, but it is a factor to be considered in the design of Tension Structures.

Shrinkage

The physical law of the Conservation of Mass states that contraction of an object in one direction is offset by expansion in one or both of the other two directions. Given the thickness of a piece of fabric is negligible compared to its length and width, it can be presumed a shrinkage in the warp direction will therefore be offset by compensating expansion in the weft.

Polycotton canvas is particularly susceptible to shrinkage. Small test samples subjected to wetting contract in both warp and weft directions, balanced by an increase in thickness. Cotton shrinks more than synthetic yarn when wetted, and therefore the higher the cotton content, the more the propensity of the canvas to shrink. The manufacturer’s recommendation is to allow for contraction in the warp of -2.5% for a 65/35 polycotton blend; and -3.0% for a 52/48 polycotton blend. In both cases the manufacturer suggests that the small compensating contraction in the weft can be ignored.

The base scrim of PVC coated polyesters and meshes are heat set before coating, and tend to exhibit much less shrinkage than canvas. When unrolled and cut, the fabric will tend to shrink in the warp direction, and expand slightly in the weft. Similarly, coated polyolefins also tend to be reasonably stable because of the thermosetting effect on the woven tapes of the coating process. The coating itself also tends to hold the fabric matrix in place, but the fabric will stretch under applied loading and react to extreme changes in temperature. Thus, some dimensional change must be expected, some permanent, the extent dependent on the environment in which the fabric is used.

As a rule of thumb, for coated products allow -0.5% shrinkage in the warp and ignore a modest expansion in the weft for fitted covers. Even though Coated PVC's and polyolefins do not have the same propensity to shrinkage as canvas, they are still just as inherently anisotropic. It is for this reason all fabrics should always be joined "warp" to "warp" or "weft" to "weft", never "warp" to "weft".

The reaction to Loading or Stress

Dimensional change also occurs as a reaction to loading, and the significance of elongation in the strength test results is often overlooked; as is the potential loss of elasticity. Rarely, in general purpose usage (as opposed to Tension Structures), is reinforced PVC tensioned deliberately, and most field loads are light, unless induced by inappropriately restrained shrinkage or wind. As with canvas, the physical law of the Conservation of Mass also applies to coated PVC's, and a contraction will occur in one direction as a result of extension in the other, as clearly indicated in Biaxial test results (refer **Figure Eight (d)**).

For this reason, in tension structures, the coated PVC is always fabricated so that its stiffer direction (i.e the warp) is aligned to that of the highest applied stress, because this minimises the dimensional change in both directions. Even in general fabrication, where applied loads are light, it makes sense to follow the same practice. An example is a truck side curtain, where the warp of the fabric should be aligned parallel with the truck body. The force in this direction is that applied by the tensioner mounted behind the cab, plus that induced by preventing the contraction otherwise caused by tightening of the buckles and hooks attached to the weft.

Tear

An understanding of the mechanism of tearing is important in order to work out the appropriate ways to prevent it. Tearing can be either "out-of-plane", like one tears a piece of paper, in which case the failure is due to shear; or "in-plane", where failure is due to fibre extension and break (refer **Figure Six**)

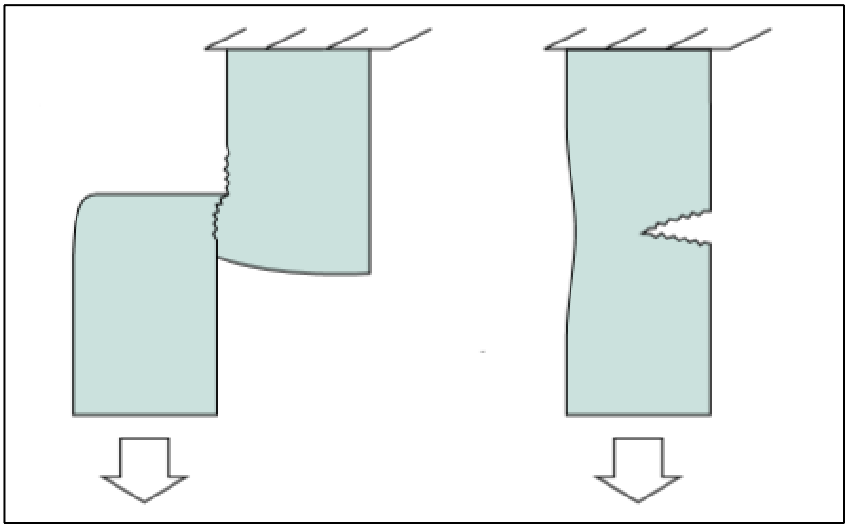


Figure Six – Different types of tear. "Out-of-plane" shear (left) and "in-plane" tensile failure (right)

Most values for tear strength published in product specifications are derived from “wing tear” or “tongue tear” tests, which model which “out-of-plane” tearing. These results are generally lower than those derived from “Trapezoidal Tear” tests which model “in-plane” tear. This is because it is easier to shear the fibres than break them (for a detailed description of these tests refer to Technical Guide Number One “How to Tell a Good Yarn – Textile Manufacturing and Testing”).

Tearing is difficult to initiate, but relatively easily propagated, especially under the action of a rapidly applied force; and can be started from the edge, or from an internal join or cut. Tearing from the edge can obviously be prevented by appropriate hemming, which should be at least three ply and if sewn, double stitched. This three ply hem also prevents the ingress of moisture into the scrim of coated fabrics (“wicking”), minimising the likelihood of unsightly internal mildew staining. Joins should be similarly overlapped.

Internal cuts should be avoided. If they are necessary, shape them without acute angles, which encourage tear propagation, and again reinforce the edge. Tearing can be initiated by a concentrated point force applied when the fabric is fully restrained. An example is the applied force of a rope through an eyelet. Because of this concentration of force at connecting points, eyelets are not particularly appropriate forms of support, even though they are almost universally used. Fabrics are best supported continuously along the edge, for example, by using kedar and a track, or a cable along the edge, which uniformly distributes reactive stress.

If eyelets are used, the bigger the better, because the reactive stress in the fabric (i.e. force per unit cross-sectional area) is directly proportional to diameter. For example, for the same applied load, the reactive fabric stress on an SP 7, which has an internal diameter of 12.7mm, will be approximately 25% less than that on an SP 4, which has an external diameter of 9.7mm. The uniform spacing of eyelets, whilst aesthetically pleasing, is not particularly efficient at distributing applied load, which tends to be concentrated at the corners. Closer spacing of eyelets toward the corners and wider spacing at the centre is more logical.

Mould and Mildew

Most Industrial Fabrics are either inherently mould and mildew resistant, or have fungicides and bactericides added to the formulation. Mould requires sustenance and moisture to survive. Thus, making sure the fabric that fabric is regularly cleaned of organic matter, and not folded or retracted when wet, goes a long way to preventing the problem.

Polycotton canvas has fungicides incorporated into the proofing, but the propensity of cotton to absorb moisture, and the possibility of pollutants, dirt and grime becoming embedded in the fabric interstices, constitute a mildew risk. This is best combatted by proper cleaning and if necessary, treatment with dilute bleach (refer “Care and Cleaning”).

Coated Polyolefins are inherently mildew resistant, and no additional anti-fungal treatment has been incorporated in the formulation of the products. PVC itself also has an inherent resistance to microbiological attack, but additives such as plasticisers and stabilisers can serve as nutrients for fungi and bacteria. In addition, the polyester scrim can absorb water through wicking at the seams, and act as an amenable environment for mildew growth. Where this is an issue, for example in the tropics, proper seam sealing is essential, and consideration should given to using ‘blockout’ fabric.

Flex Cracking and Delamination

Flex cracking, usually caused by allowing the fabric to flap in the wind, is the rupture of the surface coating, coupled with fraying of the scrim along a line of repeated flexing. A sure sign of it in coated polyolefins is a faint crazing pattern on the surface of the fabric and tarps displaying this are almost certainly no longer waterproof.

There are obvious precautions that can be taken to minimise the risk. Fabrics subject to wind load should be kept taut, and since the fabrics tend to flex along fold lines, wherever possible tarpaulins should be rolled, rather than folded. .However, the lighter weight but less flexible coated polyolefin fabrics are more at risk of flex cracking in this respect than the heavier Coated PVC's, but even these are not immune to it.

Because of their light weight and limited flex cracking resistance, Polyshield is only recommended to be used for static or temporary covers. Polypropylene has better flex resistance than polyethylene, and therefore consideration should be give to using "Flexicover" in preference to "Polyshield" where flex cracking is a concern.

PolyPlan 680 used as the cover for a walkway

Coating adhesion is the critical factor that determines both water resistance and weld strength of coated PVC's and polyolefins. "Delamination" is a commonly used industry term to describe failure in this context, but is strictly only applicable to laminated fabrics. In laminates, peeling of the surface film (i.e. de-lamination) from the scrim is a potential mode of failure, because it is applied as a solid sheet. This cannot happen in coated fabrics because the surface film is applied as a liquid. Thus, "de-lamination" in the context of a coated fabrics means separation of the coating due to its inadequate adhesion to the base scrim.

Water Penetration Resistance

Canvas requires periodic re-proofing to maintain its water repellent characteristics, and the Australian Canvas manufacturers market their own brands in this respect. Wax Convertors Textiles brand "Dynaproof" is a solvent based and available in two litre containers, and can be applied by a sponge, roller or brush. The Bradmill product "Bradproof" is water based and similarly packaged.

The products are designed to be used when weathering or cleaning has broken down the originally applied hydrophobic compound. A simple test to determine whether it is necessary is to pour a small quantity of water on the surface of the fabric. If beading occurs, the proofing is still active. If water spreads without beading, then reproofing is required. Do not use on new canvas, as it is unnecessary, and may lead to impairment of appearance.

Although the Nolan Group's coated tape polyolefin fabrics routinely perform well under hydrostatic testing, wide variation of results can be expected in practice, because of the very nature of their construction. The surface is not perfectly smooth, but has microscopic peaks and troughs where the tapes cross, resulting in variation of the coating thickness at these points, which can be exacerbated by tape folding or other variations resulting from weaving. Since water penetration resistance is directly proportional coating thickness, it cannot be expected to be uniform across the whole surface.

Coating thickness can also be reduced by abrasion, caused for example, by dragging tarps across the ground. The coating can also be ruptured by fatigue cracking or inappropriate handling and storage. Thus in practice, one should assume that the fabrics can leak at applied hydraulic pressures very much less than the laboratory test results. Therefore, wherever possible, design covers or shelters in such a way that water is encouraged to runoff, rather than allowed to pond on the surface. If this is not possible, one would be prudent to opt for double layered protection.

Fabricating Canvas

Before cutting out, allow the pieces cut from the roll to 'sit' for a long as practicable, in order to allow them to release production stresses caused by winding the fabric under tension. In the design of products, such as tenting, ensure that water is prevented from coming into contact with ancillaries such as hook and loop tape, zippers, fly-screens, binding tape etc. These products often contain wetting agents, which can be leached into the canvas, and undermining the effectiveness of the proofing.

Sewing is the only practical method of fabrication. When sewing panels together, use a double needle machine equipped with a puller. The overlap is recommended to be 20 mm. A lock stitch machine with a walking foot is suited for hemming.

Given the composition of the base fabric, it is appropriate to use a polycotton thread for joining and seaming, provided the fabricator and consumer are aware of its limitations. Coats Terco 12 (210 Tex) is the minimum size recommended, the relevant needle sizing being Nm 130 to 160 (#21 to 23 Singer size). Nonetheless, use the smallest size needle with which the machine will stitch properly. Inspect and if necessary, change needles for best results. Thread breakage is often related to a burr in the needle and not necessarily the size of the needle itself.

Alternatively, a UVR stabilized polyester thread of 135 Tex can be used, but bear in mind this thread will lose strength over time. Quality Thread and Notions B138 or Coats V138 are recommended, the relevant needle sizing being Nm 140 to 200 (#22 to 25 Singer Size). Use the same size thread for the bobbin as for the top stitch, and maintain light to medium tension on both. Good practice is to maintain 5 to 6.5 stitches per inch for general applications.

If seams are properly stitched with correct needle size, leakage is unlikely. However, even with best practice, leakage sometimes occurs. In this event, spray the seams with a seam sealer such as 303 Fabric Guard. Most fabricators use an overlap seam, which varies from 1/2" (12 mm) to 3/4" (20 mm); which is either double needled or double stitched.

Maintain tension in front of and behind the needle during the sewing process to minimise puckering/gathering of the fabric when seaming. Avoid too much back stitching because this technique can weaken the fabric and cause the fabric to tear more easily.

Fabricating Polyolefins

Welding

Coated Polyolefins can only be wedge or hot air welded. Like all thermoplastic materials, polyolefin based fabric tends to shrink with the application of heat – polyethylene more so than polypropylene – which can result in puckering along the weld itself. Strength can also be reduced by up to 20%, which can lead to tension failure in the fabric immediately alongside the weld. Given the limited coating thickness, the risk associated with welding is high.

The basic aim should be to minimise any heat transfer from the coating to the scrim, by maintaining the lowest effective temperature setting and application time. Up to a certain point, seam strength is dependent on applied heat, but too much can have the reverse effect. This 'welding window' is quite narrow, and is not the same for polyethylene and polypropylene. It will also vary depending on ambient temperature and humidity; the type and brand of equipment being used; and the medium on which the fabric is resting (i.e wooden or concrete floor).

For this reason, the welding process must be very carefully controlled, with trials done to find the optimum settings, and constant testing of joins at random throughout the process.

Caution must be exercised if attempting to weld fabrics that have been flame treated. The oxidised surface can react with moisture, resulting in the failure after a period of time of apparently initially sound welds.

Repairs to damaged tarpaulins

It is common practice to make field repairs with adhesive tape, although clearly these are never going to restore the fabric to its original integrity. For polyethylene, experience has shown that the most effective tape is Butyl Bond "Tesafix 60900" manufactured by Beiersdorf Australia Ltd (also known as BDF Ltd). Advice from the manufacturer suggests that there is no logical reason why the same tape could not be used for polypropylene, but there is no field experience in this context. No warranty is given or implied by the Nolan Group in the use of these products.

Installing dam liners

"Polyshield" is suited for use as a dam liner, and has been widely used for this purpose. To avoid the risk of puncturing the fabric, the base should be compacted, and be free of protruding rocks or boulders, preferably with a 200 mm layer of fines. A non-woven geotextile fabric should then be laid as a cushion for the "Polyshield", which is laid directly over the top of this and joined on site using portable welders. The edges can be trenched in the manner shown in **Figure A2 of Appendix A**. The dam should be backfilled with 300 mm clean loam pushed from the edge inwards. Avoid operating construction equipment directly over unprotected fabric.

Grain storage

The design of a tarpaulin covered on farm storage has been developed and successfully tested by the grain handling authorities over many years. Advice based on this experience is summarised in **Appendix A**. Using this criteria, a computer model has been developed which for a given grain type, tonnage and stack height will provide bunker dimensions and sizes of tarpaulin and ground sheet required. The model can be accessed through www.nolans.com.au

A Typical Grain Storage Facility, protected by a lightweight tarpaulin Cover

Greenhouses

In greenhouse applications, the main advantage of "Solarpro" over unreinforced polyethylene sheet is its far higher strength and dimensional stability. It will not tear as easily, and will provide greater protection against hail puncturing and subsequent roof loading. The UV stabilisers in "Solarpro" are also neutral, that is, do not absorb UV radiation, which is essential for plant growth. Because many fertilisers have a sulphur base, the warranty offered on "Solarpro" is limited to two years.

Contact of any PVC or rubber products with "Solarpro" may lead to deactivation of UV stabilisers, leading to premature fabric failure. Framing materials (even timber) therefore should only be lagged with Frameshield tape. This also minimises the risk of the fabric being damaged by heat transfer.

The lightweight Polyfab Solarfix used as the cover material for a hot-house

Fabricating Coated PVC

Colour variation and opacity

Despite careful quality control, some variations do occur between production batches. Colour match tends to be quite exact, but in coated PVC's minute differences in film thickness can occur, usually manifested as a minor difference in opacity. This is difficult to detect on the shop floor, but sometimes obvious on the finished job, especially marquees, particularly when the material is viewed from the underside. Use of a blackout for roofing is a sensible precaution, which has the added advantage of hiding accumulated surface dirt, but the option is not usually adopted for walling.

Welding

Because of their thicker coating, PVC's are generally easier to weld than polyolefins, and can be RF welded as well. There is a plethora of excellent technical publications and other material available from the machine manufacturers and trade associations that provide advice on welding. The "High Frequency Welding Handbook" produced by the UK Federation of High Frequency Welders is recommended particularly, and is the source of the "Weld Fault Finding Chart", reproduced in **Appendix B**.

Seam Sealing

In terms of avoiding problems that may arise in service, seam sealing is crucial. Wherever possible, seam in such a way that its direct exposure to the environment, and hence the ingress of moisture is prevented.

PVC coated polyester fabrics (in this case ProTEX GP) are widely used in tents and marquees

FABRICATION AND USAGE (ARCHITECTURAL APPLICATIONS)

Architectural Design

The flexibility of PVC coated fabrics allows membranes of complex shape to be fairly easily accommodated, which presents designers the opportunity to develop building themes that challenge the imagination. Perhaps the most famous example of this is the Denver Airport terminal, with its displaced conic roof profile which is designed to mimic the backdrop of the Rocky Mountains (**Figure Seven**).

Figure Seven– Denver Airport Terminal with Rocky Mountains Backdrop

However, there are pragmatic considerations, because the design approach for tension membranes is very different to that of conventional structures. The shape or form of a conventional structure is determined by the designer, which can be entirely random, and in turn leads to the nature of the loading of the structural supports.

On the other hand, with a tension membrane, the shape or form is a natural, curvilinear response to loading applied at the support boundaries. Therefore, in the design process, one is essentially choosing a set of boundary conditions which results in a shape, rather than the shape itself.

The analogy of a soapy film suspended on a ring is useful in order to understand the concept. The film relies on surface tension to remain intact, and will distort in shape in response to deformation of the support ring. Similarly, the geometry of a tension membrane is defined by its internal equilibrium of prestress, in turn dependent on the boundary conditions of support. The boundary conditions are the disposition of all the elements that contact and provide support for the membrane, for instance, ridge and edge cables, masts, arches, rings, etc. For this reason, the design of the membrane is an iterative process where the overall architectural and structural details are developed simultaneously.

Unless supported by framework, tension structures have as their basis anticlastic surface geometry, which is the result of concave curvature in one direction, balanced by convex curvature in the other, as illustrated in **Figure Eight**. There are four generic types of anticlastic surface in common use – the "cone", the "saddle", the "hypar", and the "ridge and valley".

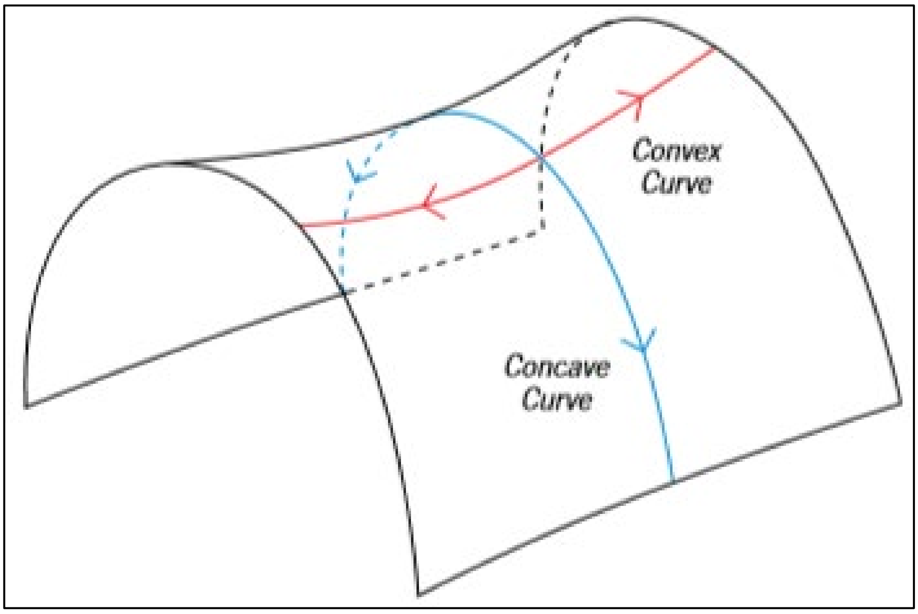


Figure Eight – Example of Anticlastic Geometry, showing the interaction between a convex and concave curve

The curvature of membranes requires space, and for this reason, they typically have exaggerated profiles in elevation, relative to that of those of a conventional roof. The flatter the elevation, the less opportunity there is to exploit the potential of the membrane to be self-supporting. Fabric used in near flat profiles tends to become mere cladding, sometimes requiring a complex supporting structure.

This is important because the supporting frame is necessarily heavier, which undermines the elegance of lightness. The same is true of other supporting elements, such as columns, which should take full advantage of the opportunity for pin joints that is provided by cable anchorage. Whilst symmetry is not essential in design, it is logical in the context of balanced loading, and avoidance in supporting members of bending moment and torsion, which immediately inflate their structural mass.

View from the underside of a mast supported conical structure

The European Classification of Coated PVC Fabrics by 'Type'

The European classifications for different 'Types' of Architectural PVC Coated Polyester Fabrics, as determined by European Standards, are reproduced in **Table Two**. Essentially, the physical differences between the types stem from variations in the yarn density; the nature of the weave of the scrim; and the applied PVC coating thickness. As a rule of thumb, the heavier the overall weight, the higher the break and tear strengths.

Table Two – European Classification of Coated PVC Fabrics by 'Type'
(Values in Italics from the French design Guide; and those in plain text from the Working Group for Architecture at Messe Frankfurt)

TYPE	One	Two	Three	Four	Five
Surface Weight (gsm)	*720* 800	*1000* 900	*1200* 1050	*1400* 1300	*2000* 1450
Yarn Linear Density (dtex)	*n/a* 1100	*n/a* 1100	*n/a* 1670	*n/a* 1670	*n/a* 2200
Tensile Strength (kN/m) (warp/weft)	*60/60* 60/60	*84/80* 88/79	*110/104* 115/102	*120/130* 149/128	*160/170* 196/166
Trapezoidal Tear Strength (N) warp / weft	*n/a* 310/350	*n/a* 520/580	*n/a* 800/950	*n/a* 1100/1400	*n/a* 1600/1800
Yarn Count (per cm) Warp / weft	*n/a* 9/9	*n/a* 12/12	*n/a* 10.5/10.5	*n/a* 14/14	*n/a* 14/14

Structural Project Tolerances

The specified tolerances of Tension Membranes are usually tight, and consequently so is that for fabrication, which is therefore is a specialist discipline, requiring considerable expertise. Most active in the industry have considerable experience, and at the very least, their shops have sophisticated CAD / CAM plotting and cutting systems. Many have inhouse engineering staff, and often, they are also engaged in installation.

The process of fabrication entails first the devolution of the three dimensional finished surface into two dimensional panels, which are then joined together, usually by welding. The fabric panels must be cut and assembled smaller than their installed size, in line with the expected ‘compensation’. The panels must be selected to accommodate the width of the fabric selected, and are often nested to maximise the yield. This means that careful labelling of each panel and marking of connection points is essential. Similarly, all other details such as reinforcements, edge cable pockets, etc, need to be incorporated.

Strength tests of welded seams is recommended to be undertaken as a matter of course, but as a guide, the welded seam widths recommended by the European design code are listed in **Table Three**. It is particularly important that the designer advise the type of lacquer specified, as this influences the welding procedure.

Table Three - Minimum welded seam width recommended by the European Design Guide

Fabric Type	One	Two	Three	Four	Five
Seam Width (mm)	40	60	80	80	100

Polyplan Fabric used for wind-rated fixed umbrellas

Pre-Stress

The effect of pre-stress is to significantly stiffen the membrane and the resultant anticlastic curvature constrains what would otherwise be severe deformations typical of flat or singly curved surfaces.

Although the geometry of a tensioned surface may be complex, all the rules of static equilibrium and balanced tension forces apply. Other structural characteristics of the surface are no compression, bending or shear. Further, the curvature of most surfaces can be reasonably approximated by circular arcs over a finite distance, which allows the simple linear equation for hoop stress to determine the relationship between applied pressure and membrane tension, as input to the iterative ‘form-finding’ process.

Generally, the minimum required pre-stress depends on the strength of the material and the curvature of the membrane surface. The larger the radii of curvature (i.e. the flatter the surface), then the larger the value of pre-stress required.

In their “pre-stress” state, fabric structures are normally designed to have uniform or smoothly varying stresses throughout their surfaces, though not necessarily equal in both directions of the textile weave. Different levels of pre-stress may alter the shape to a certain degree and may improve structural behaviour, which is particularly important in conical structures. In all cases the fabric should be aligned so that the warp and joining seams follow the direction of the highest stress.

The European Design Guide recommends a minimum prestress of 1.3% of the tensile strip capacity of the material. The Guide’s generic values are listed by product ‘type’ in **Table Four,** which are consistent with values computed for the Sattler Atlas products.

Table Four – Minimum pre-stress values recommended by the European Design Guide

Fabric Type	One	Two	Three	Four	Five
Minimum Value (kN/m)	0.70	0.90	1.30	1.60	2.00

Nonetheless, these pre-stress values are less than one tenth of the anticipated working stresses, and in practice higher values than those recommended are sometimes used; for example, to maximise the stiffness of the membrane in high windload areas. Further, given the vagaries of the fabric response, the actual pre-stress values applied during installation are often adjusted to smooth the final shape, and may be higher than those anticipated in the design phase.

Membrane structures are usually ‘compensated’ to allow for the strain associated with initial pre-stress; plus other factors such as stretch-set, creep, and elastic stretch of the cables. These latter factors can be minimised through a “force-controlled” tensioning process, where the application of load during installation is time dependent; but are more generally are simply “geometrically controlled” through allowance in the cutting out and fabrication process.

Regardless of the compensation allowed, it is important to include provision in the design of tensioning systems (e.g turnbuckles) for adjustment and/ or subsequent re-tension, should it prove necessary as a result of, for example residual material deformation or foundation settlement. If possible, the position of the supporting steelwork should be checked by site survey prior to cutting out and fabricating the membrane.

A Dual coned tension structure, fabricated from Atlas Type II, illuminated at night

Derivation of Elastic Parameters

Sattler has undertaken a number of biaxial tests over the years, in keeping with the changes in development of computational theory, and practical experience. The most recent are tests undertaken by Dekra Automobil GmbH in 2018.

These tests follow exactly the procedure outlined in the European design guide, and are primarily designed to facilitate computation of the Elastic moduli. The biaxial test results cover the load ratios of 1:1; 1:2 and 2:1 (Warp /Weft) for a working stress of one fifth the ultimate load. The working stresses are not applied simultaneously in both directions, and therefore are essentially uniaxial loads superimposed on the prestressed state. The technical reports are available on request, and include the calculated Elastic Parameters for the Atlas Range.

Interpreting Biaxial Test Results

The standard strength tests of the product specifications are uniaxial (i.e. load applied in one direction only),and report both the force and extension at break. The force is expressed as Newtons per fifty millimetres, which is the sample width, and extension as a percent of the original sample length. Graphics show that the stress / strain response is reasonably linear until failure, and hence approximates Hooke's Law.

Hooke's Law states that for an elastic material, (i.e. one that returns to its original shape like a spring after an applied load is released), there is a linear relationship between applied stress and strain, with the slope of the line termed the Modulus of Elasticity or Elastic Modulus. A material is said to be "stiff" if the line is steep, meaning the Elastic Modulus is high. Logically, the 'unhindered' (i.e. not influenced by loading in the perpendicular direction) Elastic modulus can be derived from the uniaxial tests, as well as through the procedure described in the European design Code.

Figures Eight (a) plots the relationship between stress (applied load) and strain (deformation) for both uniaxial and biaxial loading. **Figure Eight (b)** shows the loading cycle for the strain response shown.

Figure Eight (a) - Stress Strain Curve for a 720 gsm coated fabric under simultaneous 1: 1 biaxial loading

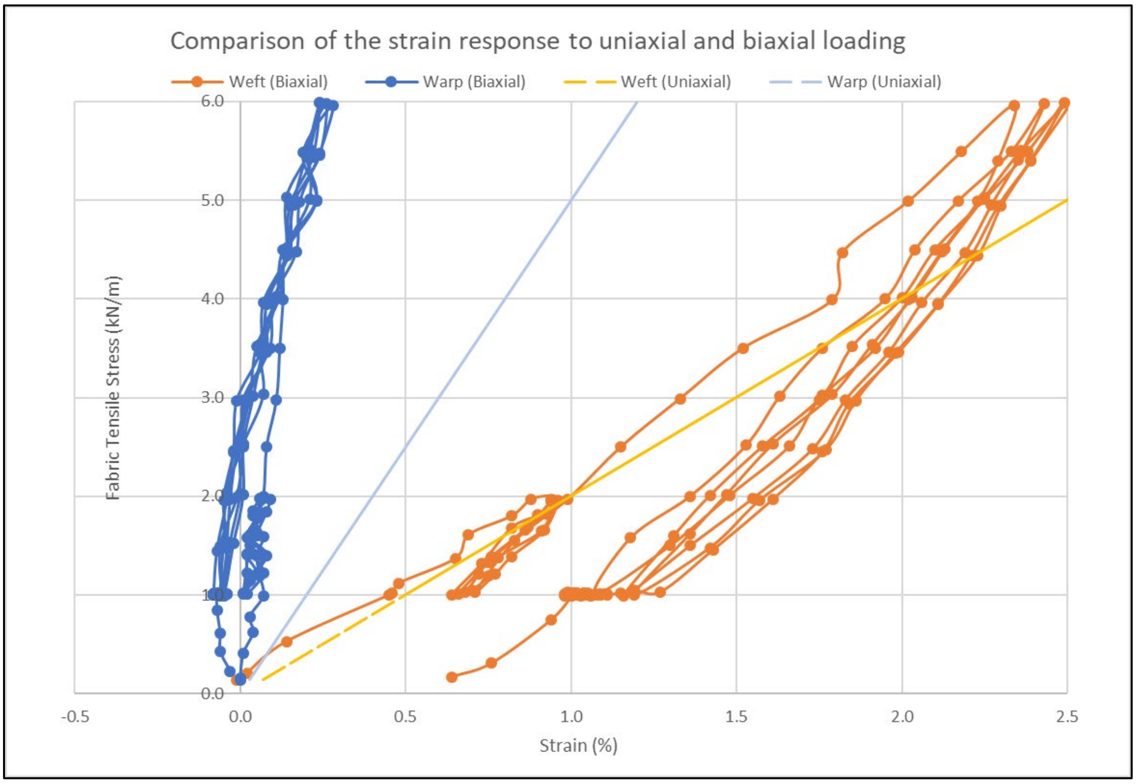
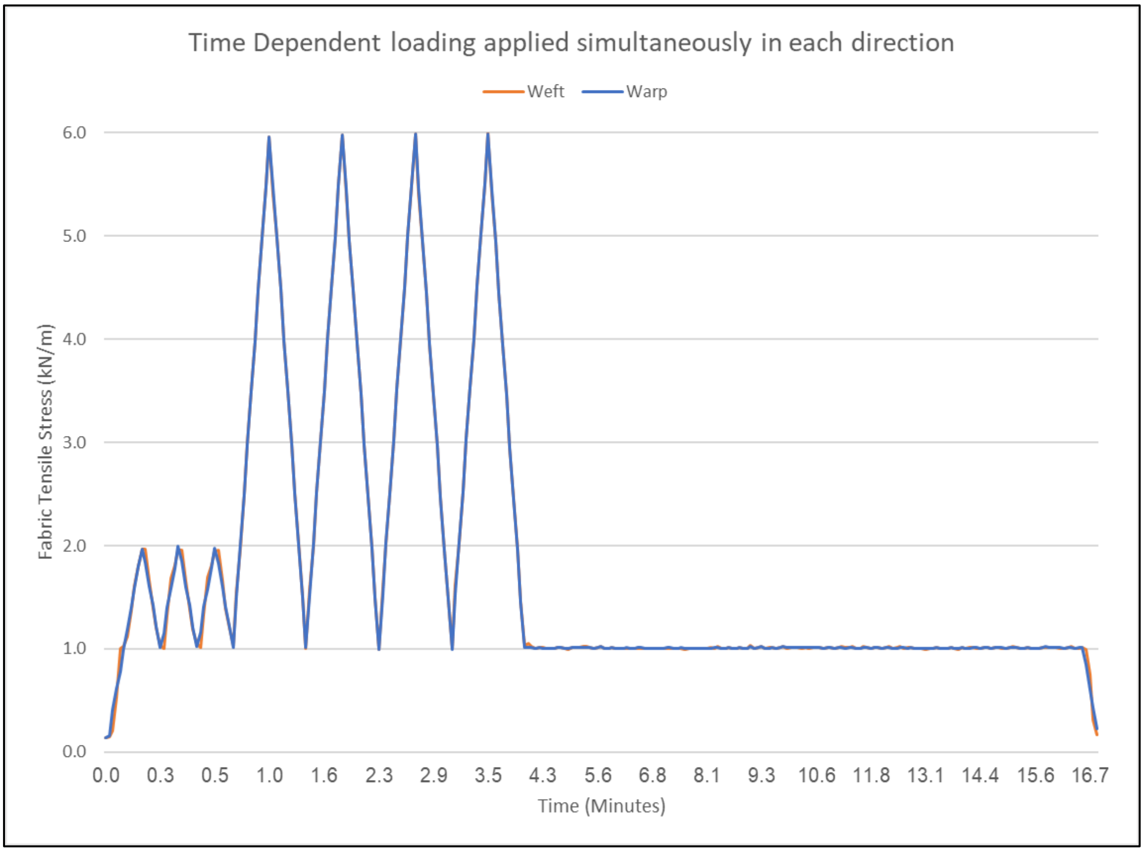


Figure Seven (b) – Loading cycle inducing the biaxial strain response plotted in figure eight (a)



Note that in this test the varied load is applied simultaneously in both warp and weft directions, which is generally not the case in most biaxial tests. Usually, a moderate load is applied in each direction, and held constant; while further dynamic uniaxial loads are superimposed in each direction at differing times (**Figure Eight (d)**). This allows the linked relationship between the opposing strains in each direction to be identified.

There are a number of relevant points to note from figure Eight (a):-

- The behaviour in each direction is different, and undergoes significant hysteresis in each loading cycle.
- The PVC Coated fabric is "stiffer" in the warp direction than in the weft..
- The fabric is permanently deformed ('stretch set') after each loading cycle and will not return to its original shape when the load is released. Hence the strain response only approximates 'elastic behaviour'.
- Under biaxial loading, the significant elongation in the weft causes very substantial contraction in the warp, resulting in a dramatic increase in stiffness in this latter direction relative to the uniaxial case.

Figure Eight (c) shows the same fabric loaded non-simultaneously to 12 kN/m, superimposed on an initial pre-stress loading of 2.5 kN/m**. Figure Eight (d)** shows the timing of that loading, with the stress plotted on the left hand scale (solid lines), and the corresponding strain on the right hand scale (dotted lines). The point loads are about twice those shown on figure eight (a), which explains the very different strain response in figure eight (c).

The first sequence of dynamic loading occurs in the warp direction between the elapsed times of thirty minutes and one hour thirty minutes. This loading induces positive strain (i.e. elongation) of approximately 2.5% in the warp direction, which increases slightly with each cycle due to the effect of "stretch-set". This positive strain induces a negative strain (i.e. contraction) of about -0.5% in the weft direction.

The second sequence of dynamic loading occurs in the weft direction between the elapsed times two hours and three hours. The loading in the warp has been reduced to the pre-stress level during these cycles. The weft load induces a positive strain of eight percent in that direction, and a negative strain of -1.5% in the opposite warp direction. Once the loading cycle has been completed, there has been a permanent "stretch-set" 0.5% in the warp, and 5.5% in the weft.

Creep

When fabrics are placed under load, creep can be significant. For example, values of creep under pre-stress loading for typical plain weave Architectural fabrics, derived from biaxial testing, are shown in **Table Five.** Note that the additional expansion in the weft direction induces further contraction in the warp direction.

Table Five – Time dependent strain values derived from biaxial testing (1:1 load ratio)

Fabric Type	Pre-stress (kN/m)	Warp strain (%) after:-		Weft Strain (%) after:-	
		t = 5 mins	t = 35 mins	t = 5 mins	t = 35 mins
One	2.4	0.07	0.05	1.26	1.41
Two	3.2	0.11	0.10	1.32	1.57
Three	4.6	0.05	0.04	1.09	1.24
Four	6.0	-0.05	-0.10	1.90	2.06
Five	8.0	-0.14	-0.19	1.60	1.75

Figure Eight(c) – Stress Strain curve for non-simultaneous 1:1 biaxial loading

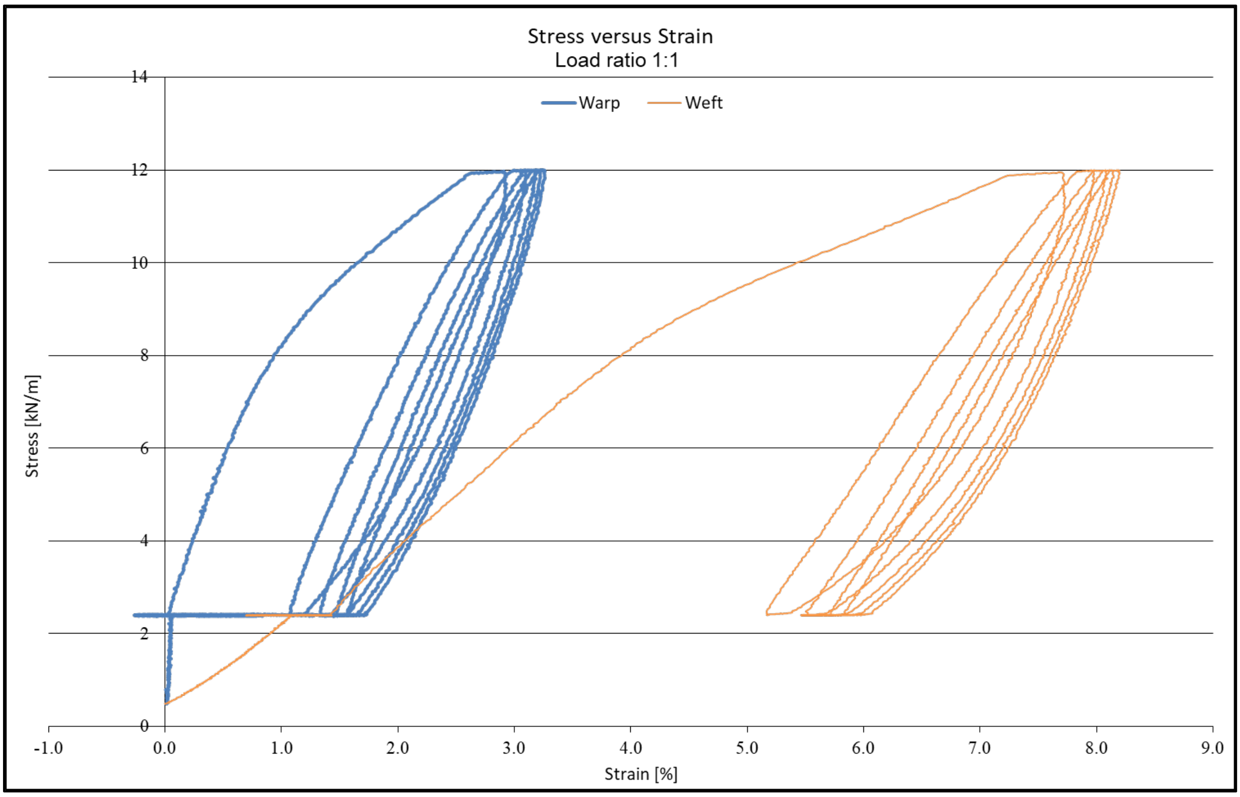
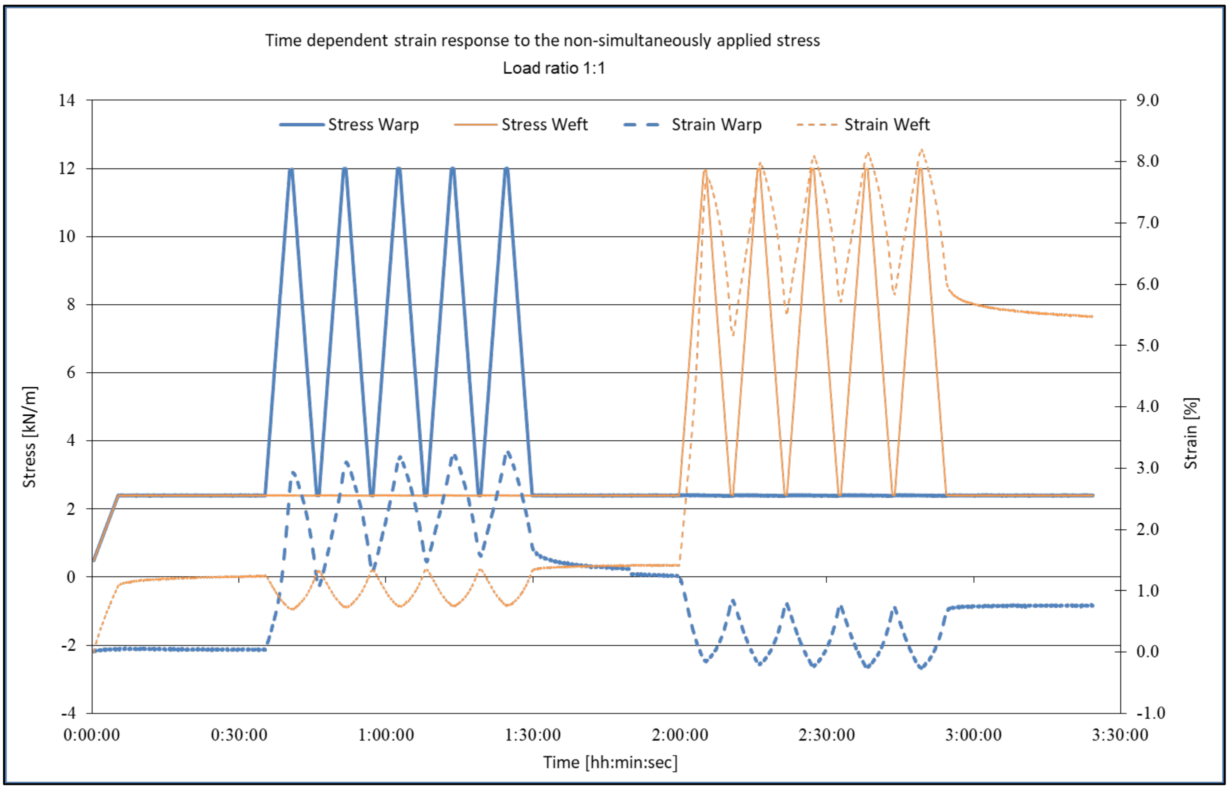


Figure Eight (d) - Loading cycle for figure eight (c), with strain superimposed

Note the correlation between the positive strain(extension) in one direction, and the negative strain (contraction) in the other.



PRINTING AND PAINTING

Surface and Ink compatibility

Most companies engaged in screen and digital printing are well aware of the intricacies of using plastics as a print medium. Nonetheless, because of their durability in outdoor environments, flexible reinforced plastics are widely used in this context, and with the inexperienced, failure of the process can be attributed to faulty material, when often this just isn't the case.

First, one must understand the dynamics of ink adhesion, which is essentially the outcome of a battle between the surface tension of the ink droplet, and the surface energy of the medium.

Surface tension is the result of the polarity of some molecules, due to asymmetry in their atomic structure. For example, water comprises a relatively large negatively charged oxygen atom, and two relatively small positively charged hydrogen atoms, clustered on one side. While the electrical charges balance overall, the asymmetrical shape of the molecule results in a positive charge on the hyrdrogen side, and a negative charge on the oxygen side. Within the body of the liquid these bi-polar charges cancel out, but at the surface they do not, resulting in stronger cohesion between the molecules at the surface, i.e. 'surface tension', which causes the liquid to form droplets.

The surface energy of the medium is a measure of its reactivity, which in a printing context is its ability overcome the surface tension of the ink droplets. For it to do so, its surface energy has to be a good deal higher than the ink drops' surface tension. Both are measured in dynes per cm, and as a rule of thumb, the surface energy of the medium has to be about 10 dynes/cm higher than the surface tension of the ink to be guaranteed to win the battle. Typical values of surface energies for plastics are shown in **Table Six**.

Table Six – Typical surface energy values of plastics (dynes/cm)

Print medium	Surface Energy (dynes/cm)
Polyethylene	31
Polypropylene	29
Polyvinyl Chloride (PVC)	33-37

Water has a much higher value of 72 dynes/ cm, which is why it will not saturate the surface of plastics, and sit as droplets on the surface. Because of additives, water based inks have Dyne values between 31 dynes/cm to 35 dynes/cm, and solvent inks lie somewhere between 28 dynes/cm and 30 dynes/cm. It's obvious from these relative values that any battle is going to be close, particularly given the statistical variability of the materials and inks, and changes in ambient conditions. Therefore, it is not surprising that one print run will be perfect, and the next problematic, even when using the same materials and inks.

The surface energy of these mediums can be increased to about 50 dynes/cm by treatment, which either oxidises or polarises the surface itself. In oxidation, negatively charged oxygen is incorporated into the molecular structure, and polarisation entails realignment of existing negatively charged atoms (e.g. the chlorine in PVC) at the surface. Methods include flame treatment; Corona Discharge treatment, which electrically charges the surface; and Plasma and Chemical treatment. These enhancements are not permanent, and wear off over time. They can also be affected by static electricity generated during handling, and by changes to the substrate itself, such as plasticiser migration.

The obvious printing strategy would be to measure the surface energy of the substrate, and the surface tension of the ink, but the available techniques for doing so are subject to error. Any printer worth their salt will take nothing for granted, and carry out their own empirical tests on the ink receptivity of the medium.

With regard to polyolefins, the Nolan Group's products are not routinely flame treated, and this treatment must be specified on order, or undertaken by the printer. It must also be remembered that oxidation of the surface affects the products' weldability, and possibly its chemical resistance. While "Polyshield" can be printed after treatment, "Flexicover" has a much smoother surface, and is therefore more suited than the former for use as banners.

The Nolan Group's PVC's are compatible with vinyl sensitive pressure lettering or graphics, vinyl based paints and solvent based screen printing inks. They are not suited to enamel paints, or the "E-stat" or "Thermal ink jet" printing processes. If an acrylic lacquer is applied on the surface, it can impact on receptiveness.

For example, truck side curtains have traditionally been painted with a 'two pack' paint, which is essentially an automotive paint with a flexible additive. This is not compatible with the dual acrylic lacquer of "ProTEX Side-Curtain", which needs to be scoured off, and treated with "Prep-sol" for this type of paint to adhere.

However, the acrylic lacquers of the Nolan Group PVC Coated products are receptive to solvent inks. The physical structure of the medium is also important, since the "ripstop" scrim of ProTEX TS or ETS or small unobserved imperfections on the surface of "ProTEX Side-Curtain", can become obvious when printed or painted. Thus, while these products are printable, they are not specifically designed for that purpose.

Plasticiser migration over time can affect ink receptiveness, which is exacerbated by exposure to heat. Check the date of production on the label, as aged stock tends to have a higher probability of the problem occurring. Always test for adhesion before any print run, and if this is a problem, it can be ameliorated by wiping the surface of the vinyl with isopropyl alcohol.

A Jumping Castle fabricated from ProTEX "Toughstuff'. With appropriate surface preparation, PVC coated fabrics can be readily printed.

Screen Printing

Following the ink manufacturers recommendations on application rates and curing times is essential. To minimise the risk of blocking, the following common sense suggestions are made:

- Reduce the total ink mass, by using the highest mesh count that is practical.
- When using solvent based inks, allow at least 24 hours drying time before screening over existing work.
- For double-sided banners, there are practical limitations on the amount of ink that can be applied on either side. This is because ink solvents become entrapped in the substrate, which can result in rewetting.
- Use slip sheets between finished banners and avoid direct contact between printed surfaces.

Wind Load on Banners – "A Hole Lot Better?"

The practice of cutting holes in banners, purportedly to allow wind to escape, is widespread. But how effective is it as a means of reducing wind load? Not very. Why? The reason is simple. The magnitude of the wind load applied to an object is directly proportional to the effective area exposed to the wind, and cutting holes does not reduce this effective area by very much. The effective area is a function of two factors. First, the wind direction. The load on the banner will be considerably less if the wind is blowing from side-on rather than front-on. The second factor is the surface area exposed to the wind.

Take as an example a three metre by one metre banner, which has a surface area of three square metres. The streamline action of the wind on this banner is shown in **Figure Nine (a).** Now let's cut some holes in it, say ten of them, each 200mm in diameter. The action of the wind now is shown in **Figure Nine (b).**

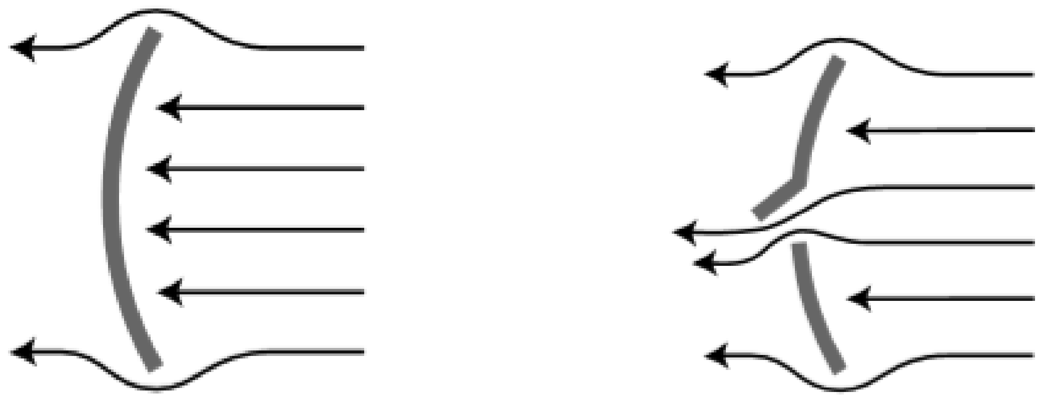
The holes allow those wind streamlines impinging directly on them to pass through, but have no effect at all on those impinging on the rest of the banner. Thus, the effect of the holes is simply proportional to their area, which can be calculated as ($10 \times \pi \times 0.2^2 \div 4$) = 0.31 square metres, about ten percent of the total surface of the banner. Therefore, the cutting of ten holes of this size has reduced the wind load by ten percent. But at the price of completely defacing the banner, as shown in **Figure Ten (a)**. Cut fewer and smaller holes? Sure, but any beneficial effect on wind load is even less, and the vandalism is still there.

Furthermore, a ten percent reduction in wind load can be achieved just as effectively by reducing the overall size of the banner by ten percent, say by folding and seaming the material 50mm along the top and the bottom, as shown in **Figure Ten (b)**. This has a significant added advantage of a 33% strengthening of the points where wind damage is most likely to occur – at the stressed eyelets.

All of this is unnecessary if a logical and comprehensive approach is taken. The limiting factor is the material itself. The heavier the supporting scrim, the better the physical properties of the material, but the less smooth the printing surface. Because of this tradeoff, most banner substrates on offer weigh about 330 gsm (10 oz/$yd^{2)}$, which is really not adequate for high wind exposure. In this environment, opt for a 440 gsm (13oz/$yd^{2)}$ or even 610 gsm (18oz/$yd^{2)}$, which has double the tensile strength and four times the tear strength of a 330 gsm material.

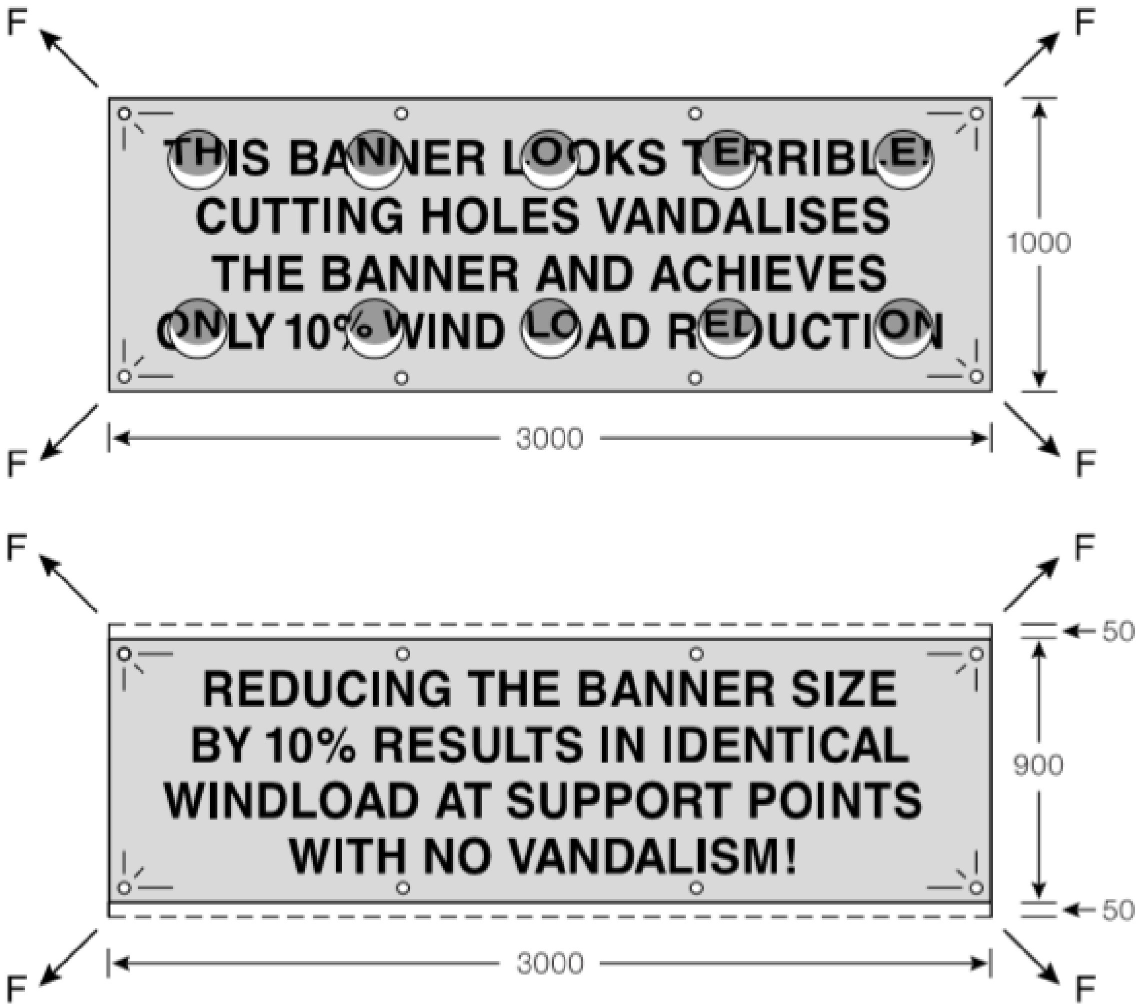
The most important factors are how the banner is fabricated and supported. Always ensure the connection points are adequately reinforced. When installed, the banner should be kept taut to reduce the likelihood of flapping, and attached from as many points as possible to avoid concentration of stress.

Figure Nine– Wind Streamlines



(a) For a banner with no holes **(b) For a Banner with holes**

Figure Ten – A banner vandalised by the cutting of "wind holes".The effect on total wind load by cutting holes is identical to reducing the overall size of the banner by the total area of the holes. The reactive force F is the same in each case.



GENERAL CLEANING AND CARE

Resistance to chemicals found in common cleaners

A summary of the chemical resistance of Polyolefins and PVC to chemicals in concentrations commonly found in household and industrial cleaners is contained in **Table Seven.** A more complete index is attached as **Appendix D**. This is general information only, since for example, additives such as colour pigment or UV stabiliser may be affected by a particular chemical, even though the base material itself may not..

Polyolefins have excellent resistance to alkalis, weak acids, alcohols and most oils and greases. They have poor resistance to halogens, such as chlorine; and halogenated hydro-carbons. They are also affected by strong oxidising agents, such as hydrogen peroxide; and chlorox (bleach), in undiluted form.

Flexible PVC is also resistant to most inorganic liquids, including moderately concentrated acids and alkalis, and aqueous salt solutions. It too is affected by powerful oxidising agents, acetone, alcohols and ammonia, chemicals sometimes found in industrial cleaners. Extreme caution should be taken if contemplating their use. When in doubt always test a sample piece.

Polycotton Canvas

When used in permanent outdoor situations, the canvas should be kept clean by brushing regularly with a soft brush and hosing with cold water. Do not allow bird droppings, dirt or vegetable matter to accumulate on the surface.

Avoid the use of soaps and detergents, and other cleaning fluids unless absolutely necessary, and be as careful with the canvas as you would be with clothing. For stubborn stains, scrub with a brush and a weak solution of household detergent or if necessary, a diluted solution of one part household bleach containing 5.25% Sodium Hypochlorite and three parts lukewarm water, of maximum temperature of 38^{o} Celsius.

Mildew should be treated the same way if it can't be removed by brushing or high pressure hose. Apply the diluted bleach solution to the fabric with a stiff brush or broom and rinse off thoroughly after fifteen minutes.

Powdered abrasives, steel wool, etc are not recommended Above all, avoid the temptation to use solvents such as petrol or kerosene, as these tend to damage the cotton fibre.

Always ensure that canvas tarpaulins are thoroughly dry before folding and storage.

To ensure that water repellency is fully retained after twelve months continuous outdoor exposure, or after aggressive cleaning, the fabric should be reproofed using the manufacturers' recommended products.

Wax Convertors Textiles brand "Dynaproof" is a solvent based and available in two litre containers, and can be applied by a sponge, roller or brush. The Bradmill product "Bradproof" is water based and similarly packaged.

Table Seven: *Compatibility of Industrial Fabrics with Common Chemicals*
(at Substantially Diluted Concentrations and Room Temperature)

Legend ✓✓*Compatible* ✓✗*Limited Compatibility* ✗✗ *Incompatible*

Alkalis or bases	Polyethylene	Polypropylene	Polyester	Cotton	PVC
Ammonia NH_3 or Ammonia Solution NH_4OH	✓✗	✓✗	✗✗	✗✗	✗✗
Calcium Hydroxide $CaOH_2$ (Hydrated Lime)	✓✓	✓✓	✓✓	✓✓	✓✓
Potassium Hydroxide KOH (Caustic Potash)	✓✓	✓✓	✓✗	✗✗	✓✓
Potassium Carbonate K_2CO_3 (Potash)	✓✓	✓✓	✓✗		✓✓
Sodium Hydroxide NaOH (Caustic Soda)	✓✗	✓✗	✓✗	✓✗	✓✓
Sodium Carbonate Na_2CO_2 (Washing Soda)	✓✓	✓✓	✓✓	✓✓	✓✓
Sodium Bicarbonate $NaHCO_3$ (Baking Soda)	✓✓	✓✓	✓✓	✓✓	✓✓
Acids					
Hydrochloric Acid HCl (Muriatic Acid)	✓✓	✓✓	✓✗	✗✗	✓✓
Nitric Acid HNO_3	✓✓	✓✓	✓✓	✗✗	✓✗
Sulphuric Acid H_2SO_4	✓✗	✓✗	✗✗	✗✗	✓✗
Acetic Acid $C_2H_4O_4$ (4% concentration in Vinegar)	✓✓	✓✓	✓✓	✓✓	✓✓
Phenol C_6H_6O (Carbolic Acid)	✗✗	✓✗	✓✗	✓✗	✓✗
Oxalic Acid $C_2H_2O_4$	✓✓	✓✓	✗✗	✗✗	✓✓
Solvents					
Acetone C_3H_6O	✓✓	✓✓	✓✓	✓✓	✗✗
Benzene C_6H_6	✗✗	✗✗	✓✓	✓✓	✗✗
Ethyl Alcohol C_6H_6O	✓✓	✓✓	✓✓	✓✓	✓✗
Isopropyl Alcohol C_3H_8O	✓✓	✓✓	✓✓	✗✗	✓✗
Mineral Turpentine $C_{10}H_{16}$ (White Spirits)	✗✗	✗✗	✓✓	✓✓	✗✗
Tetrachloroethylene C_2Cl_4 (Dry cleaning fluid)	✗✗	✗✗	✓✗	✓✗	✗✗
Trisodium Phosphate Na_3PO_4	✓✓	✓✓	✓✓		✓✓
Kerosene (Paraffin)	✗✗	✗✗	✓✓	✓✗	✓✗
Petrol	✓✗	✓✗	✓✓	✓✗	✓✗
Carbon Tetrachloride	✗✗	✗✗	✓✗	✓✗	✓✗
Oxidising Agents					
Hydrogen Peroxide H_2O_2	✓✗	✓✗	✓✗	✗✗	✓✗
Sodium Hypochlorite NaOCl (Bleach)	✓✓	✓✓	✓✗	✓✗	✓✓

PVC coated or laminated polyester

Clean regularly to avoid the accumulation of residue that could foster mildew growth and staining. To do so, first brush off loose dirt and rinse with lukewarm water. Then, wash with a sponge or soft brush, with lukewarm water and dishwashing detergent. Soak if necessary and let soap suds stand for a short while, but do not allow to dry. Rinse off soap residue with clean water. Allow retractable umbrellas and tarpaulins to thoroughly dry before closure or stowage.

In general, most soiling can be removed after repeated applications. If necessary, a 1:10 dilution of household bleach containing 5.25% Sodium Hypochlorite will not harm the fabric's surface. Moderate scrubbing with a medium bristle will help loosen the soiling agent from the depressions of embossed surfaces.

Powdered abrasives, steel wool and industrial strength cleaners are not recommended, as they will dull the surface gloss. Dry cleaning fluids and lacquer solvents attack the surface, and should not be used.

Certain stains may become set if they are not removed immediately, so act quickly. Fresh stains such as grease can be wiped with a cloth impregnated with methylated spirits, then washed with soapy water.

Dry stains should be coated with a paste made of equal parts of talcum powder and a dilute solution of bleach, allowed to dry and then cleaned off with methylated spirits.

DO NOT use industrial strength cleaners or vinyl conditioners, such as AMORALL, which tend to leach out the plasticisers, and reduce the life of the products

Coated Polyolefins

Polyolefins are inert and do not readily accumulate dirt or other residue on the surface. To clean, first brush off loose dirt and rinse with lukewarm water. Then, wash with a sponge mop or soft brush, in lukewarm water, no warmer than 50^{o} Celsius, and a non-abrasive detergent which is pH neutral. Avoid the use of concentrated bleach, chlorine, or similar halogen based products.

Be careful that the detergent does not contain acidic chemicals or solvents. Soak if necessary and let soap suds stand for a short while, but do not allow to dry. Rinse off the residue with clean water. Allow tarpaulins and temporary covers to thoroughly dry before stowage.

DETAILED PRODUCT SPECIFICATIONS

Physical Properties

The physical specifications for the Nolan Group Industrial Fabrics are tabulated in **Tables Eight** through **Fourteen** These specifications form the basis of the "Fit for Purpose" statement, and are the foundation of the product warranties. Not all these products have been tested to Australian Standards, but the methods of tests are similar, and a description of these can be found in Technical Guide Number One.

Both Bradmill and Wax Convertors Textiles (WCT) manufacture their polycotton canvas in Australia to Australian Standards. The ProTEX branded PVC's and coated Polyolefins, although manufactured in SE Asia, also have a specification drafted to meet Australian Standards.

Herculite is manufactured in the United States, and its specifications (**Table nine**) are founded on the standards of the American Society of Testing Materials (ASTM). Some properties of Herculite200 have been independently tested to Australian Standards and for completeness are included.

Sattler's Atlas brand Architectural Fabrics are manufactured in Austria, and the specifications (**Tables Thirteen and Fourteen and Twelve**) are drafted and tested to those of the International Standards Organisation (ISO) and /or to the German DIN.

SUSTAINABILITY, ENVIRONMENTAL IMPACT AND RECYCLING

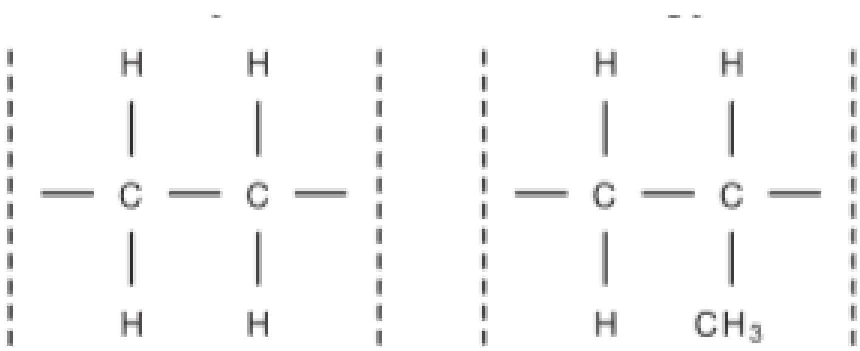
Molecular Structure of Base Materials

Polyethylene has a simple molecular structure, comprising a chain of linked Hydrogen and Carbon atoms (**Figure Eleven (a)**). Low density polyethylene (LDPE) and high density polyethylene (HDPE) are almost identical except that HDPE is more linear in structure, with less branching of the polymer chains, which results in better tensile properties.

Polypropylene is similar in structure to polyethylene, except that every fourth hydrogen is replaced with a Methyl (CH_3) group (**Figure Eleven (b)**). Although similar in structure, the change in molecular arrangement results in slightly different properties, which can be further altered by other additives, such as UV inhibitors or flame retardants. These differences are reflected in the performance attributes of the finished fabrics.

Figure Eleven – Molecular Structure of Polyethylene and Polypropylene

(a) Ethylene (b) Propylene



These monomers become polymers when the basic structure between the dashed lines is linked together into continuous chains

Polyvinyl Chloride has a similar structure to polypropylene, except that the methyl group is supplanted by a chlorine atom (**Figure Twelve**), which significantly affects its physical, chemical and electrical properties. For example, the negatively charged chlorine introduces polarity to the PVC molecule, thus making it react to an applied alternating current, which is the mechanism of RF welding. Unlike polyolefins, PVC is inherently stiff, and requires the addition by up to 23% by weight of plasticisers, which are synthetic oils, to make it flexible. Other additives comprise colour pigments, UV inhibitors, and in some cases additional fungicides and flame retardants.

Table Eight – Bradmill Polycotton Canvas Specification

Properties	Test Method	Unit of Measure	10-300 Superdux	10-373 Superdux	10-440 Superstop	32-411 Kordux
Fibre Content ratio						
Polyester		Percent	65	52	52	52
Cotton			35	48	48	48
Weight		gsm (oz/sq yd)				
Loomstate			285 (8.4)	430 (12.7)	430 (12.7)	490 (14.4)
Proofed			345 (10.1)	515 (15.2)	530 (15.6)	530 (15.6)
Finished Width		cm	200	200	200	200
Breaking Force	AS 2001.2.3A	N/50 mm				
Warp			1,840	2,415	2,350	3,500
Weft			1,300	1,765	1,800	2,800
Tear Strength (Wing Rip)	AS 2001.2.10	Newtons				
Warp			65	106	335	360
Weft			45	66	270	270
Shrinkage*		Percent				
Warp			-2.5	-3.0	-3.0	-3.0
Weft			-0.5	-0.5	-0.5	-0.5
Light Fastness	AS 2001.4.21	Range:1 to 7	7	7	7	7
Rub Fastness	AS 2001.4.3	Range:1to 5				
Dry			3-4	3-4	3-4	3-4
Wet			4	4	4	4
Hydrostatic Pressure	AS 2001.2.18	Kilopascals	>6	>6	>5	>9
Water column depth		cm	60	60	50	90
Cone leakage	AS 2001.2.18	ml	0	0	0	0

*Small test specimen is not representative of a length of fabric. In practice, change in weft dimension can be ignored.

Table Nine – Wax Convertors Polycotton Canvas Specification

Properties	Test Method	Unit of Measure	Coolabah	Billabong	Basecamp	DX 12	Bullduck TT	CS 12 TS
Fibre Content ratio								
Polyester		Percent	65	65	52	52	50	52
Cotton			35	35	48	48	50	48
Finished Width		cm	183	183	200	204	200	200
Breaking Force	AS 2001.2.3A	N/50 mm						
Warp			1,221	1,800	2,718	2,195	2,195	3,200
Weft			1,087	1,300	1,311	1,523	1,523	2,870
Tear Strength (Wing Rip)	AS 2001.2.10	Newtons						
Warp			39	66	80	116	207	250
Weft			28	42	52	68	125	190
Shrinkage (warp)*		Percent	-2.0	-2.0	-2.0	-2.5	-2.0	-2.0
Hydrostatic Pressure	AS 2001.2.18	Kilopascals	>7.5	>7.5	>8.0	>8.0	>10.0	>8.0
Water column depth		cm	75	75	80	80	100	80
Cone leakage	AS 2001.2.18	ml	0	0	0	0	0	0

Table Ten – Herculite Laminated PVC Specification

Properties	Australian Test Method	Unit of Measure	Herculite 2000	US Test Method	Unit of measure	Herculite 80 grade	Herculite 2000
Finished Weight		gsm	610		oz / sq yd	18.4	17.9
Finished Width		cm	200		inches	60	78
Adhesion					lbs/2 ins	20	14
Breaking Force	AS 2001.2.3A	N/50 mm		ASTM D-5034-95	lbs		
Warp			1,455			330	240
Weft			1,207			328	228
Tear Strength (Tongue Tear)	BS 3424.5	Newtons		ASTM D-2262-83	lbs		
Warp			458			122	115
Weft			549			132	115
Hydrostatic Burst				ASTM D751A	psi	500	390
Hydrostatic Pressure	AS 2001.2.18	Kilopascal	>250				

Table Eleven – Nolan Group's coated polyolefin products specifications

Properties	Test Method	Units of Measure	Solarpro	Polyshield	Flexicover
Yarn Type			Polyethylene	Polyethylene	Polypropylene
Yarn Density		Denier	1000	1500	1100
Pick count		per cm	10 x 10	12 x 12	7 x 8.25
Nominal Weight		gsm	180	250	350
Coating Thickness		microns	45	55	80
Tensile Strength	AS 2001.2.3	N/ 50 mm			
Warp			1,000	1500	2800
Weft			935	1600	2400
Wing Tear	AS 4878.7	Newtons			
Warp			188	290	320
Weft			166	307	300
Flex Cracking	AS 4878.9	Cycles	100,000	100,000	400,000
Temperature Resistance		^{o}Celsius	-30^{o}/+70^{o}	-30^{o}/+70^{o}	-30^{o}/+70^{o}
Hydrostatic Pressure	AS 2001.2.17	kilopascals		215	400
Bursting Force	AS 2001.2.19	Newtons	1224	1922	
Bursting Pressure	AS 2001.2.4	kilopascals	1900	3150	

Table Twelve – ProTEX branded PVC coated polyester (Industrial Fabrics) Specifications

Properties	Test Method	PT Extra	Spanlite	GP	ToughStuff	Side-curtain	TS	ETS
Yarn Density (d'tex)		500	500	1,100	1,100	1,100	1,100	1,100
Weave Type and Pick count		Plain weave	Plain weave	Plain Weave	Plain Weave	Panama Weave	Tearstop	Tearstop
(number per cm)		7 x 7	8 x 7	9 x 9	9 x 9	(6 x 2) x (6 x 2)	8 x 8.5	8 x 8.5
Scrim Weight (gsm)		80	100	200	200	260	220	220
Coating Mass (gsm)		420	437	480	410	640	460	460
Coating Adhesion (N/50cm)	AS 4878.8	70	70	100	100	100	100	100
Total weight (gsm)		500	537	680	610	900	680	680
Tensile Strength (N/50 mm)	AS 4878.6							
Warp		2283	2763	2874	2327	3844	3245	3279
Weft		1795	2678	2668	2104	3265	2800	3066
Elongation at Break (%)	AS 4878.6							
Warp		19.5	21.4	18.0	16.9	19.5	20.7	19.5
Weft		24.8	28.5	27.5	22.4	24.5	28.5	29.0
Wing Tear (Newtons)	AS 4878.7							
Warp		232	437	217	267	508	463	327
Weft		154	208	206	157	428	398	292
Flex Cracking after:-	AS 4878.9							
200,000 cycles		slight			nil	nil	slight	
400,000 cycles					slight	slight		
Temperature Resistance		-30º/+70º	-30º/+70º	-30º/+70º	-30º/+70º	-30º/+70º	-30º/+70º	-30º/+70º
Acrylic Lacquer		Top Side	Both Sides	Both Sides	Both Sides	Both Sides	Both Sides	Both Sides
Fire Rating AS 2930 (1)	AS 2755.2		Pass	Pass	Pass	Pass	Pass	Pass
Flammability Index (2)	AS 1530.2		One	One	One			
Spread of Flame Index (3)	AS 1530.3		8	zero	zero			
Smoke Developed Index (3)	AS 1530.3		8	7	7			

Notes: (1) The pass criterion under AS 2930-1987 "Textiles – Coated Fabrics for Tarpaulins" is "Failure to Burn to 1st Marker Thread after sixteen seconds".
(2) Flammability Index has a range from Zero (non-flammable) to One Hundred (highly flammable)
(3) Both the Spread of Flame and Smoke Developed Indeces are ranked on a logarithmic scale from Zero (low) to Ten (high)

Table Thirteen – Atlas PVC coated polyester (Architectural Fabrics) bSpecifications

Properties	Test Method	730 Atlas Type One	739 Atlas Type Two	759 Atlas Three	760 Atlas Type Four	780 Atlas Type Five
Total weight (gsm)	DIN EN ISO 2286-2	700	900	1200	1350	1550
Tensile Strength (N/50 mm)	DIN EN ISO 1421					
Warp		3700	5000	6000	8600	9750
Weft		3400	4300	5500	8400	9750
Wing Tear (Newtons)	DIN 53 363					
Warp		400	600	700	1300	1700
Weft		350	550	700	1300	1700
Adhesion (N/50 mm)	DIN EN ISO 2411	120	140	150	150	150
Flex Cracking (100,000 cycles)	DIN 533 59 A	Nil	Nil	Nil	Nil	Nil
Cold Crack (^{o}Celsius)	UNI EN 1876-1:2000	-40^o	-50^o	-45^o	-45^o	-50^o
Heat resistance (^{o}Celsius)	IVK/pkt. 5	+70^o	+70^o	+70^o	+70^o	+70^o
Colour Fastness to light (Scale 1 to 7)	DIN EN ISO 105-B02	7	7	7	7	7
Visible Light Transmission (%)	EN 410	8.93	6.46	4.41	4.29	2.99
Total Solar Radiation:-	EN 410					
Transmitted (%)		10.49	7.79	5.46	5.34	3.81
Reflected (%)		80.04	81.54	83.38	82.24	84.78
Absorbed (%)		9.47	10.68	11.16	12.42	11.42
g-value (1)	EN 410	0.13	0.11	0.08	0.09	0.07

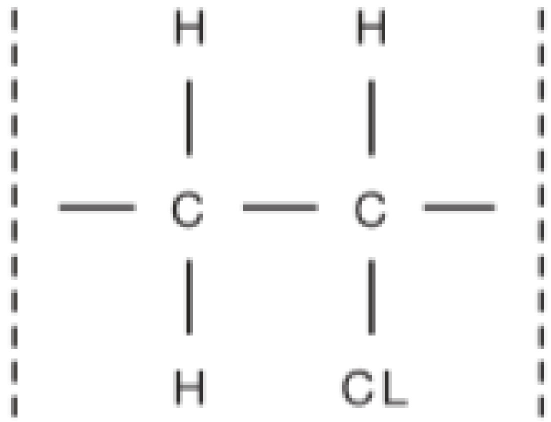
Notes: (1) The g-value is a European measure of solar energy transmittance through the medium, ranging from 0.0 (none) to 1.0 (100% transmission)

Table Fourteen – Polyplan PVC coated polyester (Architectural Fabrics)

Properties	Test Method	680 Standard	680 Blockout	680 Low Wick	745 Matt	787 Blockout	Candy Translucent
Total weight (gsm)	DIN EN ISO 2286-2	670	780	670	640	780	690
Tensile Strength (N/50 mm)	DIN EN ISO 1421						
Warp		3000	3000	3000	2600	3000	3000
Weft		3000	2800	2800	2500	2800	3000
Wing Tear (Newtons)	DIN 53 363						
Warp		300	300	300	250	300	300
Weft		300	280	280	250	280	300
Adhesion (N/50 mm)	DIN EN ISO 2411	120	110	110	100	100	100
Flex Cracking (100,000 cycles)	DIN 533 59 A	Nil	Nil	Nil	Nil	Nil	Nil
Cold Crack (^{o}Celsius)	UNI EN 1876-1:2000	-30^{o}	-45^{o}	-45^{o}	-45^{o}	-45^{o}	-45^{o}
Heat resistance (^{o}Celsius)	IVK/pkt. 5	+70^{o}	+70^{o}	+70^{o}	+70^{o}	+70^{o}	+70^{o}
Colour Fastness to light (scale 1 to7)	DIN EN ISO 105-B02	7	7	7	7	7	7
Fire Test results							
Flammability Index (1)	AS 1530.2	One					
Spread of Flame Index (2)	AS 1530.3	Zero					
Smoke Developed Index (2)	AS 1530.3	7					

Notes: (1) Flammability Index has a range from Zero (non-flammable) to One Hundred (highly flammable)
(2) Both the Spread of Flame and Smoke Developed Indeces are ranked on a logarithmic scale from Zero (low) to Ten (high)

Figure Twelve – Molecular Structure of Polyvinyl Chloride

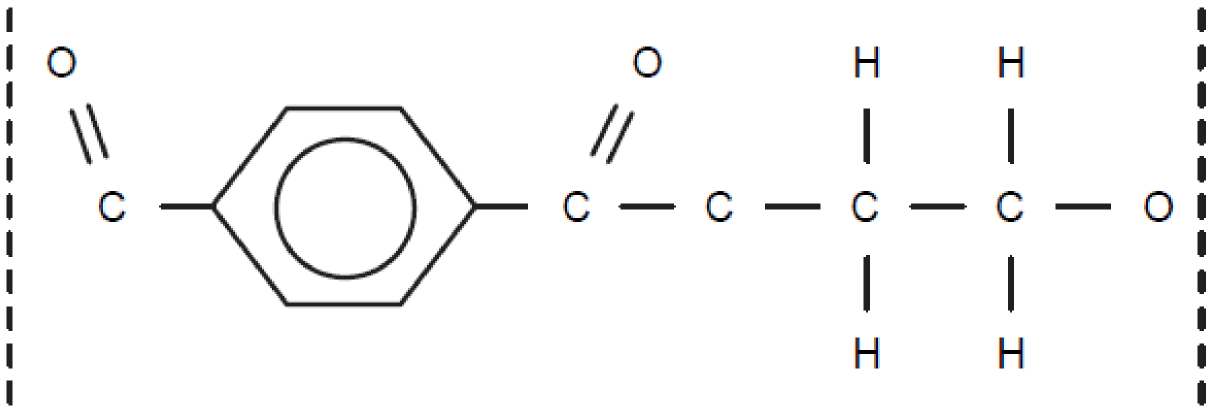


This structure is very similar to that of Olefins
but the inclusion of the negatively charged Chlorine atom
significantly changes its properties

Polyester is a generic term that describes a continuous chain of the ester functional group, which is particular chemical compound formed by the reaction of an oxoacid (i.e an acid that contains oxygen), and a hydroxyl compound (i.e one that contains covalently bonded oxygen and hydrogen as a radical). There are different types of polyester, some of which in fact occur naturally, but in most cases the nomenclature is generally interpreted to be the synthetic compound polyethylene terephalate (PET).

PET is formed from the esterfication of terephalic acid and glycol, with subsequent polymerisation of the monomer; and has the chemical structure shown in **Figure Thirteen.**

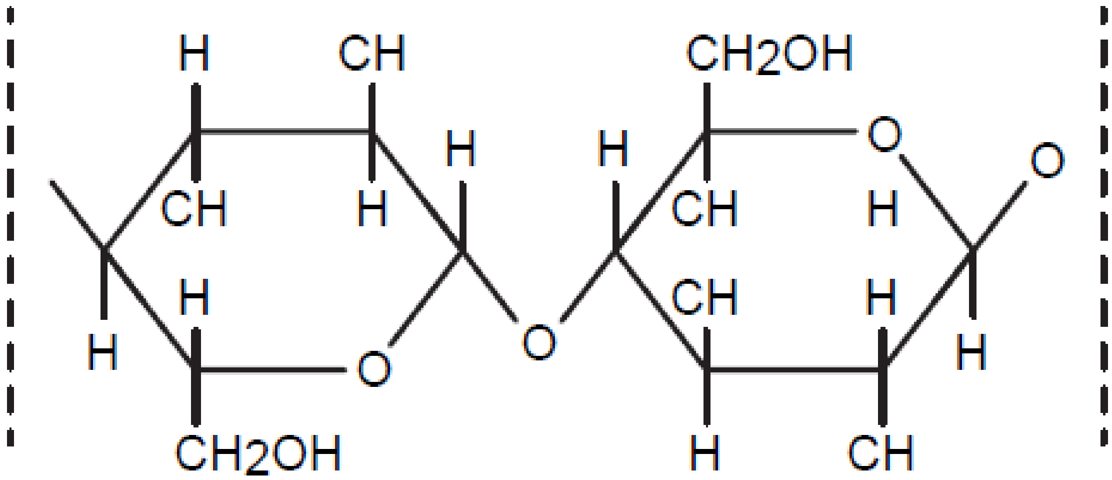
Figure Thirteen – Molecular structure of Polyethylene terephthalate (PET)



In this depiction, the hexagonal shape represents the 'aromatic ring'
of tightly bonded carbon atoms, which is very common in hydrocarbons. The dashed lines represent
the repetitive molecule in the polymer.

Cotton is a naturally occuring polymer, composed of pure cellulose, which is a carbohydrate. Its structure, which is a long chain of glucose or sugar molecules, is shown in **figure fourteen**.

Figure Fourteen – Structure of Cellulose (cotton)



The dashed lines denote the repetitive molecule, which is flipped successively in the chain.

PVC Coated Polyesters

By far the majority of the smaller membrane structures are fabricated from PVC coated polyester. The environmental 'footprint' of these structures is intrinsically low, because in practical terms the self-weight of the membrane is negligible. Hence, the ratio of live (i.e. applied) load to dead load (i.e. self weight), an inherent measure of the efficiency of construction materials, is many times larger than for other roofing materials.

Given its expected life of between fifteen and twenty-five years, proven by field usage, PVC coated polyester scores highly in a life cycle analysis. It is safe to handle, fabricate, and in a building context, has too little mass available to contribute to the fuel load of a fire. It has excellent UV and heat absorption characteristics.

If one defines sustainable as "meeting the needs of the present, while ensuring that future generations have the same opportunities"; it can be argued that coated PVC is a sustainable product. Its components are intrinsically recyclable, even though separation is not an easy process or arguably cost effective.

The process of production of polyester or PET is relatively simple, and it is usually manufactured in a closed loop, with low emissions to the environment. The raw materials and by-products of manufacture also have low toxicity, and the product itself has excellent mechanical and chemical properties. PET has many applications, from clothing to drink bottles, and is readily recyclable, provided the feedstock is not too contaminated, which can be problematic in some circumstances. As a compound, it is comprised simply of carbon, hydrogen and oxygen, making it a potentially a clean energy resource (through incineration), when recycling is not an option.

PVC is also recyclable, energy and resource efficient to manufacture, and being derived from the most basic of hydrocarbons and salt, is a low consumer of non-renewable resources.

Nonetheless, environmental groups such as Greenpeace have argued for discontinuance of PVC production, because of dioxins produced during manufacture and allegedly from incineration of waste.

Dioxins are an undesirable and inevitable by-product of vinyl chloride production, but the quantities released are low, less than 0.5% of the total generated by industry, and have been significantly reduced over the last thirty years by tighter control of the manufacturing process. PVC produces hydrochloric acid on combustion, but studies in Europe indicate that that the chlorine found in dioxins emitted through incineration are not derived from the flue gases, but from the reaction of other inorganic chlorides with graphitic ash particles; in other words, from sources not related to PVC. This is by no means conclusive, and contradicted by other studies.

Incineration is therefore considered an unsatisfactory method of product disposal. An alternative is landfill, but the stability and chemical resistance of the polymer means that it takes a long time before degradation occurs. Nonetheless, rapidly biodegradable forms of PVC are available, and will probably supplant current formulations in the future.

Recycling is an option, and the technology is presently available to separate the constituents, but unfortunately not yet in Australia. Nonetheless, it is possible to ship fabric overseas, but the practicality of cost effective and environmentally logical recycling ultimately depends on the logistics of collection, transport and re-processing.

The technology is based on the patented 'Texiloop' process, which entails chemical separation of the constituents, and then separate re-cycling of the PVC resin and PET. The used fabric is mechanically cut into small pellets, and all heterogeneous materials, such as metallic parts, are separated and removed. The plasticised PVC is dissolved in a ketonic solvent at 115° Celsius, while PET fibres remain in suspension, and subsequently recovered by filtration and drying. The PVC is precipitated out of the solvent, filtered and additives are introduced to restabilise the resin. The solvent can be re-used in a closed-loop process.

Because of the Greenpeace stance, the use of PVC in buildings is controversial. In 2007, the Technical and Scientific Advisory Committee of the US Green Building council rated PVC poorly, because of the risk of Dioxin emissions, but concluded that "no single (alternative) material shows up as the best across all the human health and environmental impact categories, nor as the worst". Further, the CSIRO, in a study conducted in a response to a call from Greenpeace for a boycott of PVC prior to Sydney 2000 Olympics, concluded that in an environmental context, PVC performs as well or better than alternative materials.

Polycotton Canvas

While it is easy to recycle cotton or polyester individually, blended fibres are tightly bonded, so mechanical separation doesn't work and chemical separation has had, until recently both practical and environmental problems related to the disposal of the reagents.

However, recent research into the use of alternate solvents has yielded results. An example is that undertaken by Deakin University using an ionic liquid (salt in a liquid state), which dissolves the cotton and allows it to be readily reclaimed, with the salt solution fully recycled back into the process..Both the cotton and polyester can be regenerated into fibres, or in the case of polyester reused as other PET based products.

Coated Polyolefins

Because of their homogeneity, coated polyolefins can be readily recycled, but the efficiency and yield depends on the condition and homogeneity of the used material, which needs to be a clean as possible to minimise contamination. The main recycling opportunities are re-use (which is generally limited to raw material recovery at the factory), mechanical or chemical recycling, and energy recovery through controlled combustion.

Mechanical recycling is the most widely practiced in Australia, since it is relatively easy and economic; and the infrastructure for collection and reprocessing is well established. Mechanical recycling is essentially the reprocessing of the plastic waste into secondary raw materials by physical means, through a series of treatments and preparation steps. The first stage includes collecting, sorting, shredding, milling, washing, and drying the plastic waste into recycled plastic pellets, powder, or flakes. In the second stage, these are converted to a molten state and reprocessed into other products using resin moulding techniques.

Mechanically recycled products, however, often have mediocre mechanical properties in practice, which strongly limit their applicability and market demand. There are two reasons for this. The first is thermomechanical degradation caused by high temperature or shearing during their processing stage. The second is that long exposure to the air, light, moisture, temperature, and weathering gives rise to natural aging during the service life of plastic products. These problems are worsened if there is heterogeneity of the plastic waste being treated, typically a mixture of various types and grades of polymers with distinct degrees of polymerization and chemical structures, which are mutually incompatible. This, coupled with contaminants, such as paper scraps and adhesive additives, deteriorate the mechanical properties of recycled polymers and limit their applications.

Although not common in Australia, chemical recycling is the conversion of polymers back into a monomer form by one of two processes, namely pyrolysis, which is the breakdown of material at elevated temperatures in the absence of oxygen, or solvent dissolution, which involves selective extraction of polymers using solvents.

GLOSSARY OF TECHNICAL TERMS

Anisotropic	Describes a fabric where the response to loading (i.e. strain or elongation) is different in the x and y directions. A fabric is isotropic if the response to loading is the same, or similar, in the x and y directions.
Anticlastic	A geometrical shape which is the result of concave curvature in one direction, and convex curvature in the other.
Biaxial Loading	Loading applied in two directions at the same time. By contrast, uniaxial loading is applied only in one direction.
Blockout	A coating substrate designed to prevent light penetration through the fabric. Compensation An allowance
Breathability	The propensity of a fabric to allow moisture vapour, (as opposed to water droplets) to pass through it.
Compensation	An allowance in the design of the theoretical finished surface profile of a tension membrane to account for the strain associated with initial pre-stress.
Creep	A time dependent increase in strain exhibited by a material under a constant load.

D'tex	A measure of weight per length of a yarn namely, grams/ 10,000 metres. Refer also D'Tex and Denier.
Delamination	A term used to describe the separation or breakdown of the surface coating from the base fabric.
Denier	A measure of weight per length of a yarn namely, grams/ 9,000 metres. Refer also Tex, and D'Tex . These can be compared by careful conversion of the units used, which are usually rounded. For example 1100 denier is equivalent to 120 Tex and1200 D'Tex.
Elastic Modulus	The relationship between applied stress (force) and resultant strain (elongation)
Filament	A continuous length of extruded fibre
Flammability Index	A test result of AS/NZS 1530.2, expressed on an empirical scale of zero (low) to 100 (high), designed to be a measure of the extent to which the test specimen burns, and the heat generated.
Flammability Indices	A generic term that describes the four indices that comprise the test results of AS/NZS 1530.3. These are completely different from the 'flammability index' of AS/NZS 1530.2.
Flame Retardant (FR)	A term used to describe yarns or fabrics that have had their inherent response to applied flame altered by the addition of chemical suppressants.
Hydrophobic	A tendency to repel of fail to mix with water. The opposite characteristic is Hydrophilic.
Hysteresis	The looped, curvilinear response to loading and unloading that is typical of coated fabrics. In contrast, the curve for a material not exhibiting hysteresis is a single, although not necessarily straight, line.
Isotropic	Having stress vs strain characteristics which are the same in each direction. The opposite is anisotropic.
Panama Weave	A type of heavy duty weave where yarns are woven in a two x two pattern. It is typically specified in a 900 gsm Truck Side Curtain fabric. (refer **Figure Five**).
Pick Count	The number of yarns per unit length of the fabric, usually quoted *per centimetre*. However, some Asian and all North American manufacturers quote *per inch.*(Rarely is the unit length given, a scrim being described for example, as simply 9 x 9 x 1100 denier. This could mean nine yarns per cm each direction, or nine yarns per inch. Given that there are 2.5 centimetres in an inch, there is a significant difference, which may be fairly obvious when visually inspecting physical samples, but not when simply comparing written specifications).

Polyolefin	A commonly used chemical nomenclature that describes a family of similar hydrocarbon polymers, the most well known being polyethylene and polypropylene.
Polymer	A continuous chains of a distinct molecular structure linked in a repetitive way.
Poissons Ratio	A measure of the proportional extent to which the width contracts to an applied load in the length direction and vice versa.
Pre-stress	The loads applied to the boundaries of a tension membrane that determines its form.
PVC	An abbreviation of Polyvinyl Chloride, which is a polymer comprising a simple compound of Carbon, Hydrogen, and Chlorine atoms.
PVDF	A non-reactive, thermoplastic fluoropolymer (polyvinylidene fluoride), that has high chemical resistance, and is applied as a lacquer finish to coated PVC's. Scrim Woven base fabric that provides tensile and shear strength and resistance to dimensional change.
Scrim	The base fabric of a laminated or coated fabrics
Stiffness	A term used to rate the relative strain response to applied stress. The stiffer the fabric the less the extension under an applied load.
Stretch-Set	The initial inelastic response and permanent deformation of a fabric under the action of applied load.
Tearstop Weave	A type of weave where a yarn is duplicated or heavier yarn inserted periodically in the weave matrix.
Tenacity	The tensile strength of a yarn
Tex	A measure of weight per length of a yarn namely, grams/ 1,000 metres. Refer also D'Tex and Denier.
Warp	Longitudinal direction along a roll of fabric.
Weft	Horizontal direction across a roll of fabric.
Weft Insertion	A type of scrim where the weft yarns are laid on top of those of the warp, and knitted together at the overlap points by a third, lighter denier tie yarn.

Appendix A DESIGN OF ON FARM GRAIN STORAGES

Introduction

The concept of fabric covered grain storages was originally developed by Bulk Grain Queensland. It is simple, practical has been used successfully in field situations around Australia. Literature describing the basic design and containing tables of bunker and tarpaulin dimensions has been widely distributed to the farming industry by fabricators and convertors of polyolefin and PVC coated fabrics. This has been reviewed by a civil engineer, and a computer model “grain bunker calculator” developed to replace the tabular data, which can be accessed through www.nolans.com.au . This appendix reproduces the construction and installation advice contained in the original publication.

Design of the bunker

A bunker storage consists of a cleared, levelled elevated area bounded on three sides by low retaining walls. The whole area is lined with a plastic groundsheet, and filled with grain, over which a suitable cover sheet is placed and sealed to keep out water, insects and other contaminants. The concept is illustrated in **figure A1**.

The bunker dimensions are determined by five variables - the stack height, the tonnage and type of grain, and the height and batters of the retaining walls. These five variables are the initial input to the “grain storage calculator”

The crucial factor is the stack height, that is, the maximum height to which the grain handling equipment can form a stack of grain. It is the stack height, together with the height of the retaining walls that determines the width of the bunker.

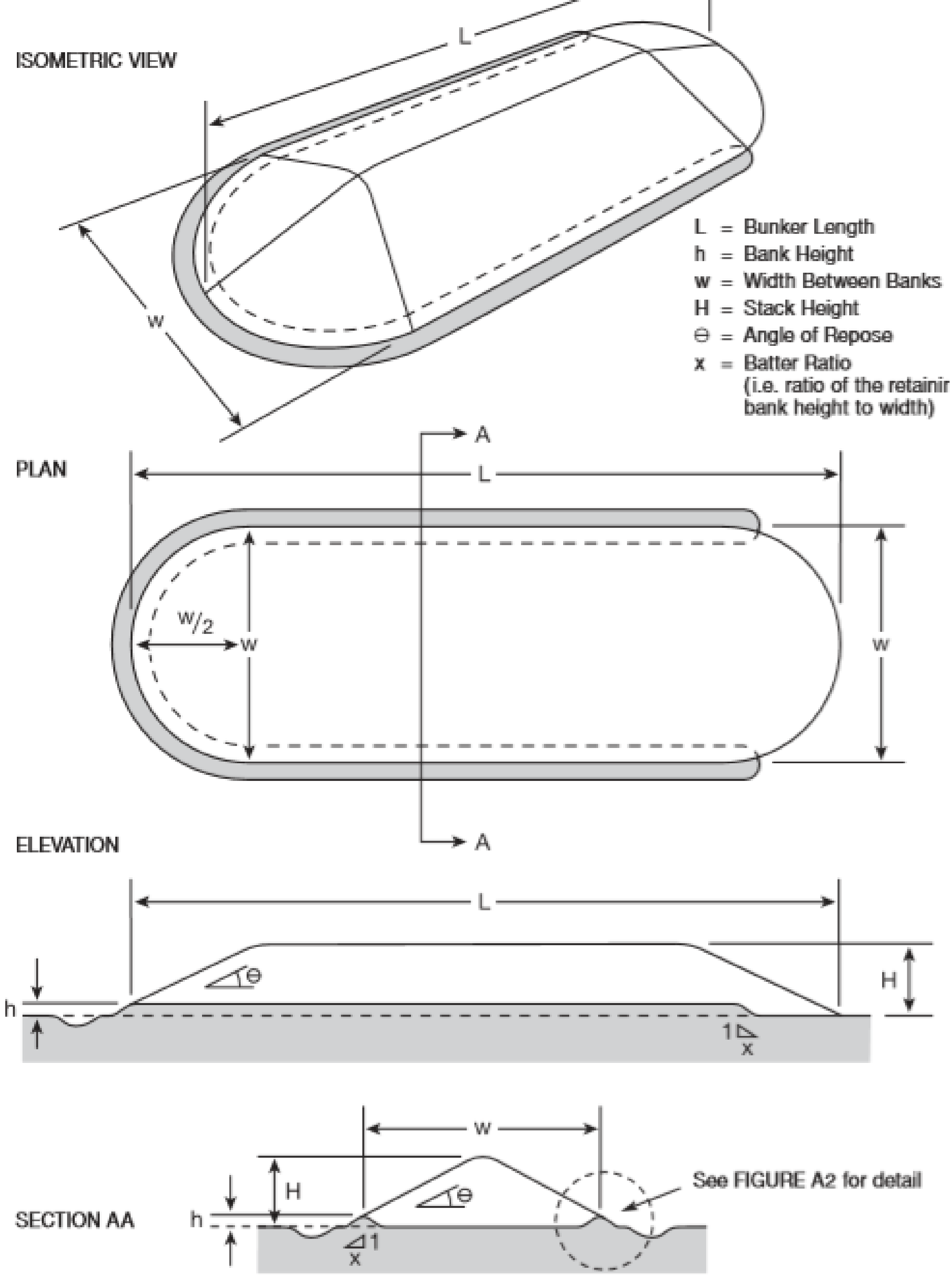
The bunker length, that is the distance from the outermost point of the circular perimeter to the tail of the grain at the open end, is a function the tonnage to be stored, but is also slightly influenced by the batters of the retaining banks, expressed as a ratio of the bank height to width **(refer figure A2).**

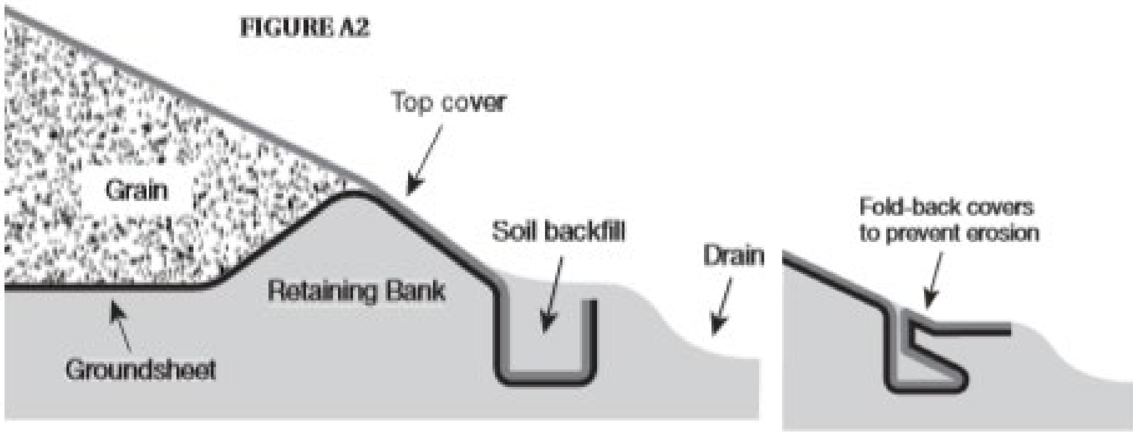
The initial output from the “Grain storage calculator” is the width and overall length of the bunker, which immediately provides an idea of the scale of the project. The computer model also prompts for a selection of fabric for both cover and groundsheet. If a selection is made, the relevant dimensions to the nearest half roll (allowing for joins) and overall weight of both are provided as output, together with the “edge allowance”, that is, the amount of material available to seal the storage outside the boundary of the grain.

The selection of material is dependent on the degree of risk one is prepared to accept. Because of the risk of puncturing or tearing, the use of non-reinforced plastic is not recommended.. Both the polyolefins and PVC’s listed in **tables one and two** have been successfully used for temporary covers on site storage of grain. As a rule of thumb, the heavier the cover, the more security provided. Polyshield is generally used as a liner for the floor and walls, and although it can be used a short-term tarpaulin cover, the heavier Flexicover (350 gsm Polypropylene) or Spanlite (530 gsm PVC) or PT Extra (500 gsm PVC) are recommended for the longer term or where multiple re-use is envisaged.

The “grain storage calculator” model allows an iterative process of design to be easily accomplished. One needs to take into account not just whether or not the overall size of the required storage can be accommodated on the site selected, but the resultant weight and size of the groundsheets and tarpaulins. There are obvious practical difficulties of unfurling and furling large, heavy groundsheets and tarps. Based on field experience, these should have a maximum area of 1500 square metres or weight of 400 kilograms. While these can be joined on site, it is not easy to so, and it is better to have a number of smaller storages with a single homogeneous cover than a one large site with multiple joins.

FIGURE A1 – Grain Bunker Dimensions





Fabrication of the covers

There are a number of workshops throughout the country that specialise in the fabrication of single, piece large groundsheets and tarpaulins. A list of these can be obtained from the Australian Canvas and Synthetic Products Association from their website www.acaspa.com.au.

Construction of the bunker

The bunker must be sighted on a well drained area where the water table is well below the surface. The site(s) must be accessible, and located away from any trees likely to drop limbs on the finished bunker(s).

Vegetation should be cleared, and the ground levelled. The retaining walls can be constructed of earth, up to one metre high if the soil is readily compacted, or half a metre if not. A minimum batter ratio of 1:1.5 should be adopted. Alternatively, grain bags can be used to form a low height vertical wall.

The semi-circular end shape is designed to accommodate the natural shape of a heaped grain pile and avoids the need to fill corners with grain.

Construction of a proper drain outside the retaining walls is essential. The base should be at least 0.5 metres lower than the base of the retaining wall and have minimum batters of 1: 5, and a minimum fall of 0.5%, but preferably 1.0 to 2.0%.

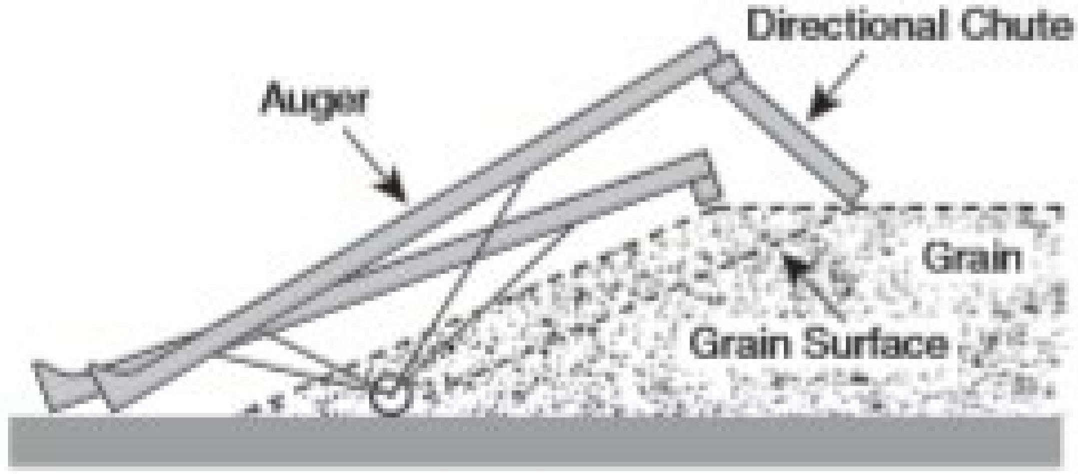
Lining, filling and covering the bunker.

The base is lined with the prefabricated groundsheet before filling the bunker. The liner extends over the earthen banks and anchored in a trench as shown in **figure A3**. An alternative detail if grain bags are used is also shown.

Bunkers are simply filled by dumping grain from a truck into an auger (or grain thrower) located midway between the side walls. The auger must be positioned far enough back to prevent the undercarriage being excessively buried by grain during filling. A directional chute attached to the outlet of the auger can be a valuable aid when filling, as it directs the grain further from the outlet, preventing undercarriage burial, as shown in **Figure A4**.

Grain should not be stared at greater than 12% moisture content. As the bunker fills, the auger is moved progressively towards the open end, taking care not to tear or puncture the ground sheet. However, it is prudent to have spare ground sheet material and Tedsafix tape on hand to make repairs. The grain peak should be at its design height and uniform along the full length of the bunker. Hand trimming of the stack before covering is necessary to avoid depressions in the grain mass or along the top of the wall where water may pond on the cover.

FIGURE A3



The bunker does not have to be completely full before starting to cover the grain. The cover is fitted by hand by a team of men progressively dragging the concertina fabric from the filled end across the top of the stacks. The cover is tensioned over the retaining banks and the end and edges sealed. One of the simplest and more successful practice requires both groundsheet and cover to extend about one metre beyond the base of the wall. These edges are buried in a previously dug trench about 250 mm deep at the base of the wall as shown in **figure A2.**

Used tyres, sand filled wheat bags or other ballast can be placed on and around the top cover to hold it down and reduce wind flap. Avoid objects with sharp projections that may puncture or abrade the cover.

Appendix B – WELD FAULT FINDING CHART

FAULTS	CAUSES																																																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Weld Opens Up	●		●		X	●		●	X							●				●		●		●		●					●	●	●	●													X	●			●	●
Film Breaks on Edge of Weld				●			●						●	●							●	●		●			●	●		●	●							●		●												
Film Breaks Within Weld							●				●	●		●	●		●							●				●		●																						
Poor Resistance to Tear Propagation				●							●	●	●	●	●											●	●																									
Bursting of Tear Seal on Inflation							●					●		●					●				●																●													
Tear Seal not Properly Welded (Ragged Tear Line)	●	●				●									●			●		●		●	●	●	●															●								●			●	
Deformed Welds					●	●		●																																●												
Formation of Bulges and Blisters on Reverse Side of Weld		●		●						●																●																										
Poor Weld Impression and Variation within Weld					●	●		●								●	●				●			●																												
Gloss Variation next to weld				●																	●																				●											
Air Inclusion in Welded Articles with Card Inserts																																										●	●									
Formation of Folds (corrugation)																													●															●	●	●	●					
Tendency for Arcing (especially with thin and rigid films)		●		●		●						●				●				●		●	●		●										●	●	●												●	●	●	
Surface Scorching						●		●															●											●	●																	
Large Surface Welding (differential energy distribution)	●					●																●		●																												●
X = refers only to the bonding of coated film to coated boards																																																				

Appendix B (Continued) **Weld Fault Finding chart – Causes key**

1. HF Output Insufficient
2. HF Output too high
3. Welding Time too short
4. Welding Time too long
5. Cooling Time too short
6. Pressure too low
7. Pressure too high
8. Depth stop incorrectly set
9. Electrode too narrow
10. Electrode too wide
11. Book cover spine weld too narrow
12. Faulty Weld design
13. Edge of weld too sharp
14. Electrode penetrates too deeply (especially on folding welds)
15. Difference in height of weld to tear seal too small
16. Difference in height of weld to tear seal too high
17. Height of electrodes does differentila thickness of layer
18. Tear seal too blunt
19. Tear seal too sharp
20. Temperature of Electrode too low (where heater box is used)
21. Temperature of Electrode too high (where heater box is used)
22. Temperature variation over electrode area (i.e. hot spots and cold spots)
23. Famaged or dirty tools
24. Insufficient rigidity in electrode mountings
25. Unsuitable Barrier Material
26. Thermal Barrier Material too thick
27. Film too Brittle
28. Card Inserts too tight fitting
29. Tension due to shrinkage of film
30. Excessive stress
31. Wear on Electrode
32. Delamination of surface coatings
33. Plasticiser exudation
34. Dirty Surface
35. Conductive printing Inks
36. Film contains impurities (recyclate)
37. Packaged material electrically conductive
38. Layers of different hardness
39. Material Layers too thick in contour (tear seal) welding
40. Torn when too warm
41. Tendency of film to gloss
42. Missing or insufficient packing
43. Card insert too thin
44. Film not restrained
45. Poor alignment or orientation of the film
46. Film may significantly variable thickness
47. Unsuitable adhesive coating
48. Excessive Weld Area/Genenerator Output ratio
49. Insufficient Weld Area/Genenerator Output ratio
50. Unfavourable generator characteristics
51. Material unsuited to welding
52. Maladjusted Standing Wave Connectors

Appendix C - NOLAN GROUP PRODUCT WARRANTIES

C 1 Polycotton Canvas

The Nolan Group warrants that the Polycotton Canvas manufactured by either Bradmill Outdoor Fabrics or Wax Convertors Textiles (WCT) is specifically designed to be used for the designated purpose, and is guaranteed to be supplied free of defects.

The 'designated purpose' of the respective products are as outlined in the company's "Fabricator Catalogue", website www.nolans.com.au or other sales literature.

'Free of Defects' means that the products meet their published descriptions and technical specifications, and are homogeneous in appearance after allowance for minor variance, including cosmetic faults that are generally acceptable against industry benchmarks, that is inherently the result of the manufacturing process.

The Nolan Group further warrants that the products will perform satisfactorily when used for its designated purpose in the temperate climatic conditions experienced throughout Australia.

'Satisfactorily' means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and Weathering, such as gradual loss of surface proofing, colour fading, strength loss, and dimensional change. Extreme climatic conditions, particularly high temperature and humidity, may accelerate this inevitable product degradation.

'Expected Life' is at least the period covered by warranty, provided the products are installed properly, and cleaned and maintained as recommended.

The warranty specifically excludes imperfections such as creasing and folds caused by handling during fabrication, installation or operation; mechanical fatigue due to wind load, and damage attributable to faulty design or installation, such as abrasion by componentry; or tear caused by undue concentration of stress at supports; to storm or cyclone events, including hail loading; and to vandalism.

The warranty period is THREE YEARS for both Bradmill and WCT fabrics.

The liability of the Nolan Group is limited under this warranty to replacement of material only, or refund of the original invoice price, both options with a discount on value for the time the fabric has been in place, on a pro-rata basis as follows:-

The first half of the warranty period	Nil Discount
The third quarter of the warranty period	50% Discount
The final quarter of the warranty period	75% Discount

Liability for negligence (e.g careless operation, inappropriate cleaning procedures), or for any consequential loss, including labour and installation, is expressly excluded.

In the event of a claim, proof of purchase must be provided. In the event of a dispute, the determination of the manufacturer or recognised industry association is the sole basis on which replacement or refund is made.

This limited warranty shall under no circumstances override legal guarantees that may be required under the Consumer Act. The warranty is not transferrable and applies only to the original purchaser.

The Nolan Group Warranty is independently supported by those of our Suppliers:-

Bradmill Outdoor Fabrics Unit 3 100 Fulton Drive Derrimut VIC 3030 www.bradmilloutdoor.com.au

Wax Convertors Textiles 77 racecourse Rd., Rutherford NSW 2320
waxcon@waxcon.com.au

C 2 ProTEX branded PVC Coated Polyester Fabrics (Industrial)

The Nolan Group warrants that its ProTEX branded PVC Coated Polyester Fabrics are specifically designed to be used for general outdoor and industrial purposes, and are guaranteed to be supplied free of defects.

'Free of Defects' means that the products meet their published descriptions and technical specifications, and are homogeneous in appearance after allowance for minor variance, including cosmetic faults that are generally acceptable against industry benchmarks, that is inherently the result of the manufacturing process.

The Nolan Group further warrants that the products will perform satisfactorily when used for their designated purpose, as defined in the company's "Fabricator Catalogue", in the temperate climatic conditions experienced throughout Australia.

'Satisfactorily' means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and Weathering, such as stiffening and surface degradation due to gradual loss of plasticiser, colour fading, strength loss, and dimensional change. Extreme climatic conditions, particularly high temperature and humidity, may accelerate this inevitable product degradation.

'Expected Life' is at least the period covered by warranty, provided the products are fabricated and installed properly, and cleaned and maintained as recommended.

The warranty specifically excludes imperfections such as creasing and folds caused by handling during fabrication, installation or operation; mechanical fatigue due to wind load, and damage attributable to faulty design or installation, such as abrasion by componentry; or tear caused by undue concentration of stress at supports; to storm or cyclone events, including hail loading; and to vandalism.

The warranty period is TWO YEARS.

The liability of the Nolan Group is limited under this warranty to replacement of material only, or refund of the original invoice price, both options with a discount on value for the time the fabric has been in place, on a pro-rata basis as follows:-

The first half of the warranty period	Nil Discount
The third quarter of the warranty period	50% Discount
The final quarter of the warranty period	75% Discount

Liability for negligence (e.g careless operation, inappropriate cleaning procedures), or for any consequential loss, including labour and installation, is expressly excluded.

In the event of a claim, proof of purchase must be provided. In the event of a dispute, the determination of the manufacturer or recognised industry association is the sole basis on which replacement or refund is made.

This limited warranty shall under no circumstances override legal guarantees that may be required under the Consumer Act. The warranty is not transferrable and applies only to the original purchaser.

C 3 PVC Coated Polyester Fabrics (Architectural)

The Nolan Group warrants that its PVC Coated Polyester Fabrics manufactured by the Sattler Group, and marketed under the Polyplan and Atlas brands are specifically designed to be used for Textile Architecture, and are guaranteed to be supplied free of defects.

'Free of Defects' means that the products meet their published descriptions and technical specifications, and are homogeneous in appearance after allowance for minor variance, including cosmetic faults that are generally acceptable against industry benchmarks, that is inherently the result of the manufacturing process.

The Nolan Group further warrants that the products will perform satisfactorily when used for their designated purpose in the temperate climatic conditions experienced throughout Australia.

'Satisfactorily' means with continued but gradually diminished utility over its expected life, due to the unavoidable effects of Ultra-Violet Radiation and Weathering, such as stiffening and surface degradation due to gradual loss of plasticiser, colour fading, strength loss, and dimensional change. Extreme climatic conditions, particularly high temperature and humidity, may accelerate this inevitable product degradation.

'Expected Life' is at least the period covered by warranty, provided the products are fabricated and installed properly, and cleaned and maintained as recommended.

The warranty specifically excludes imperfections such as creasing and folds caused by handling during fabrication and installation; chemical attack by pollutants or application of aggressive solvents; mechanical fatigue due to wind load; damage attributable to faulty design or installation, such as faulty welds or undue concentration of stress at supports; to storm or cyclone events, including hail loading; and to vandalism.

The warranty period is SEVEN YEARS for PolyPlan; and FIFTEEN YEARS for Atlas.

The liability of the Nolan Group is limited under this warranty to replacement of material only, or refund of the original invoice price, both options with a discount on value for the time the fabric has been in place, on a pro-rata basis as follows:-

The first half of the warranty period	Nil Discount
The third quarter of the warranty period	50% Discount
The final quarter of the warranty period	75% Discount

Liability for negligence, or for any consequential loss, including labour and installation, is expressly excluded.

In the event of a claim, proof of purchase must be provided. In the event of a dispute, the determination of the manufacturer or recognised industry association is the sole basis on which replacement or refund is made.

This limited warranty shall under no circumstances override legal guarantees that may be required under the Consumer Act. The warranty is not transferrable and applies only to the original purchaser.

Appendix D – CHEMICAL RESISTANCE OF COATED FABRICS AT 20⁰ CELSIUS*

S= Satisfactory L=Limited Resistance U=Unsatisfactory T = Testing possibly required

Agent	Concentration (%)	Polyethylene		Polypropylene	PVC
		Low Density	High Density		
Acetaldehyde	40%	T	T	T	U
	100%	U	U	U	U
Acetic Acid*	10%	S	S	S	S
	20%	S*	S*	S*	S
	50%	L	S*	S*	S
	>80%	L*	L*	S*	U
Acetic Anhydride		U	U	U	U
Acetone*		S	S	S	U
Acetophenone		T	T	L	U
Acetylene*		U	L*	L*	S
Andipic Acid*		S*	S*	S*	S
Allyl Alcohol	96%	S	S	S	U
Allyl Chloride		S	S	S	U
Alum		S	S	S	S
Aluminium Chloride		S	S	S	S
Aluminium Fluoride		S	S	S	S
Aluminium Hydroxide		S	S	S	S
Aluminium Nitrate		S	S	S	S
Aluminium Oxychloride		S	S	S	S
Aluminium Sulphate		S	S	S	S
Ammonia (Dry Gas)		S	S	S	S
Ammonia (Liquid)*	100%	S*	S*	S*	U
Ammonium Carbonate		S	S	S	S
Ammonium Chloride		S	S	S	S
Ammonium Fluoride*	25%	S	S	S*	S*
Ammonium Hydroxide	25%	S	S	S	S
Ammonium Nitrate		S	S	S	S
Ammonium Persulphate		S	S	S	S
Ammonium Phosphate		S	S	S	S
Ammonium Sulphate		S	S	S	S
Amyl Acetate*	100%	U	L*	U	U
Amyl Alcohol	100%	S	S	S	S
Aniline*		L*	S*	S*	U
Antimony Trichloride		S	S	S	S
Aqua Regia*		U	L*	L	L*
Barium Chloride		S	S	S	S
Barium Hydroxide		S	S	S	S
Benzaldehyde*		U	U	L*	U
Benzene		U	U	U	U
Benzyl Chloride*		T	T	S	L*
Benzoic Acid*		S	S	S*	S*
Benzyl Alcohol*		T	T	S*	U
Borax		S	S	S	S
Boric Acid		S	S	S	S
Bromic Acid	10%	S	S	S	S
Bromine Liquid*	100%	U	L*	U	U
Butane*		U	U	S*	S
Butyl Acetate*		U	L*	S*	U
Butyl Alcohol*		S	S	S	S*

*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

Appendix D (continued) – CHEMICAL RESISTANCE OF COATED FABRICS AT 20⁰ CELSIUS*

S= Satisfactory L=Limited Resistance U=Unsatisfactory T = Testing possibly required

Agent	Concentration (%)	Polyethylene		Polypropylene	PVC
		Low Density	High Density		
Butyric Acid	20%	U	U	S	U
Calcium Chloride		S	S	S	S
Calcium Hydroxide		S	S	S	S
Calcium Nitrate		S	S	S	S
Calcium Sulphate		S	S	S	S
Carbon Bisulphide		U	U	U	U
Carbon Disulphide		U	U	U	U
Carbon Tetrachloride*		U	U	U	L*
Carbonic Acid		S	S	S	S
Chloral Hydrate		U	U	U	S
Chlorine Gas*		L*	L*	S*	S*
Chlorine Liquid		U	U	U	U
Chlorine Water*	20%	L*	S	S	S
Chlorobenzene*		U	L*	U	U
Chlorosulphonic Acid*		U	U	L*	L*
Chromic Acid	10%	L	S	S	U
	50%	U	S	L	U
Chromium Plating Solution*		U	S	S	S*
Citric Acid	10%	S	S	S	S
Copper Chloride		S	S	L	S
Copper Sulphate		S	S	L	S
Cresol		U	U	U	U
Crude Oil*		U	U	L*	L*
Cyclohexanol		L	S	S*	U
Cyclohexanone		U	U	U	U
Dibutyl Phthalate*		T	T	S*	U
Dioxane*		U	U	S*	U
Ether		U	U	U	U
Ethyl Acetate*		L*	L	S	U
Ethyl Alcohol	30%	S	S	S	S
	100%	S	S	S	S
Ethyl Ether*		U	L*	L*	L*
Ethylene Bromide		U	U	U	U
Ethylene Dichloride		U	U	U	U
Ethylene Glycol		S	S	S	S
Ferric Chloride		S	S	S	S
Ferrous Chloride		S	S	S	S
Ferrous Sulphate		S	S	S	S
Fluorine Gas*		U	L*	U	U
Formaldehyde*	30%	S*	S	S	S
Formic Acid	10%	S	S	S	S*
	50%	S	S	S	S*
Freon 12*		S*	S	S	S
Gas Natural*		U	L*	S*	S*
Gasoline (Petrol)		L	L	U	L
Glycerol (Glycerine)		S	S	S	S
Glycol		S	S	S	S
Heptane*		U	L*	L*	L
Hexane*		U	U	L*	S*

*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

Appendix D (continued) – CHEMICAL RESISTANCE OF COATED FABRICS AT 20⁰ CELSIUS*

S= Satisfactory   L=Limited Resistance   U=Unsatisfactory   T = Testing possibly required

Agent	Concentration (%)	Polyethylene		Polypropylene	PVC
		Low Density	High Density		
Hydrochloric Acid	20%	S	S	S	S
	40%	S	S	S	S
Hydrocyanic Acid		S	S	S	S
Hydrofluoric Acid*	25%	S*	S	S	S*
	40%	S*	S	S	S*
	100%	L*	S*	L*	S*
Hydrogen Peroxide*	30%	S*	S	S	S
	90%	U	L	S*	S
Isopropyl Alcohol		S	S	S	S
Keresone*		U	L*	L*	S
Lubricating Oils*		U	L*	L*	S
Magnesium Chloride		S	S	S	S
Magnesium Sulphate		S	S	S	S
Mercuric Chloride		S	S	S	S
Mercury		S	S	S	S
Methyl Alcohol	100%	S	S	S	S
Methyl Ethyl Ketone		U	U	U	U
Methyl Sulphate*		U	U	L*	S
Methylene Chloride*		U	U	L*	U
Mineral Oils*		L*	S*	L*	S
Naphtha		U	L	U	U
Napthalene*		L*	L*	L	U
Nickel Chloride		S	S	S	S
Nickel Sulphate		S	S	S	S
Nitric Acid*	10%	S	S	S	U
	100%	U	U	L*	U
Nitrobenzene		U	U	S	U
Oleic Acid		S	S	S	S
Olive Oil*		S*	S*	S	S
Oxalic Acid	10%	S	S	S	S
Phenol*		U	L*	L*	L*
Phosphoric Acid*	10%	S	S	S	S*
	75%	S*	S	S	S*
Photographic Chemicals		S	S	S	S
Potassium Bicarbonate		S	S	S	S
Potassium Carbonate		S	S	S	S
Potsssium Chloride		S	S	S	S
Potsssium Hydroxide*	10%	S	S	S	S
	50%	S*	T	T	S
Potassium Nitrate		S	S	S	S
Potassium Permanganate		S	S	S	S
Potassium Sulphate		S	S	S	S
Propane*		U	U	L*	S
Propyl Alcohol		S	S	S	S
Propylene Dichloride*		U	U	L*	U
Pyridine*		S*	S*	L	U
Salt (Sea) Water		S	S	S	S
Silcone Oil*		T	T	S	S*
Silver Nitrate		S	S	S	S

*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

Appendix D (continued) – Chemical Resistance of coated fabrics at 20^{o} Celsius*

S= Satisfactory L=Limited Resistance U=Unsatisfactory T = Testing possibly required

Agent	Concentration (%)	Polyethylene		Polypropylene	PVC
		Low Density	High Density		
Soaps (In Solution)		S	S	S	S
Sodium Acetate		S	S	S	S
Sodium Bicarbonate	10%	S	S	S	S
Sodium Bisluphate		S	S	S	S
Sodium Carbonate		S	S	S	S
Sodium Chlorate		S	S	S	S
Sodium Chloride		S	S	S	S
Sodium Hydroxide	10%	S	S	S	S
	50%	S	S	S	S
Soadium Hypochlorite*	20%	S	S	S*	S
Sodium Nitrate		S	S	S	S
Sodium Sulphide		S	S	S	S
Sodium Thiosulphate	25%	S	S	S	S
Stannous Chloride*		S	S	S	S*
Steraic Acid	100%	S	S	S	S
Sulphur Dioxide*		S	S*	S*	S*
Sulphuric Acid *	10%	S	S	S	S
	50%	L	S*	S	S
	95%	U	L*	S*	S
Sulphurous Acid	10%	S	S	S	S
	100%	S	S	S	S
Tartaric Acid		S	S	S	S
Tetrahydrofuran*		U	L*	L	U
Thionyl Chloride		U	U	U	U
Toluene		U	U	U	U
Trichloroethylene		U	U	U	U
Tricresyl Phosphate*		L	S*	S*	U
Trisodium Phosphate		S	S	S	S
Turpentine*		U	U	L*	S*
Urea		S	S	S	S
Vinegar		S	S	S	S
Xylene		U	U	U	U
Zinc Chloride*	10%	S	S	S	S*
Zinc Sulphate		S	S	S	S

*Note: Chemical resistance to the compounds highlighted deteriorates at higher operating temperatures

Nolan Group Locations

Nolan Group

Industrial Fabrics Division

SYDNEY

3 Bradford Street, Alexandria

NEWCASTLE

16 Ironbark Close, Warabrook

BRISBANE

14 Lions Park Drive, Yatala

MELBOURNE

7 Conifer Crescent, Dingley Village

ADELAIDE

489 Cross Keys Road, Cavan

PERTH

22 Hazelhurst Street, Kewdale

1300 35 75 85

Nolans.com.au

info@Nolans.com.au