1

Carpet Manufacturing

This project is supported by

International Fibre Centre

Supporting Training & Education in Textiles
# Index – Carpet Manufacturing

## Carpets – Summary

- What is Carpet? 1
- History of Carpet 1
- Fibres in Carpets 3
- Carpet Textures 3
- Choice of Fibre 4
- General Performance Characteristics of Fibres 5
- Summary of the Path of Fibres/ Filament to Floorcovering 6
- Processing Path of Yarn to Floorcovering 7
- Carpet Grading Schemes 8

## Wool as a Carpet Fibre

- Fibre Production 9
- Wool Keratin 9
- Fibre Structure 10
- Fibre Characteristics 11
- Dyeing 11
- Fibre Production and Processing Flowchart – Natural Fibre - Wool 12

## Yarn Production

- Summary 13
- Semi-Worsted System 13
- Blending 13
- Carding 14
- Drawing 14
- Spinning 14
- Yarn Twist 14
- Twisting & Winding 15
- Hanking 15
- Summary of the Semi-Worsted System 15
Carpet Manufacturing

- **Woollen System**
- Blending & Oiling
- Carding
- Condensing
- Spinning
- Twisting and Winding
- Hanking
- **Summary of the Woollen System**
- Twist Factors of Woollen and Semi-Worsted Singles & Folding Yarns
- Twist Directions for Carpet Yarns
- Felted Yarns
- Treatment of Wool Carpet Yarns
- **Setting**
- Autoclave Setting
- Chemical Setting
- Melt Fibre Setting
- Water Setting
- Continuous Setting
- **Insect Resist**
- Static Control
- **Anti-Soil & Anti-Stain Treatments**

**Man Made Carpet Fibres**

- **Summary**
- Fibre Production and Processing Flowchart – Synthetic – Nylon (Polyamide)
- Fibre History
- Polyamide
- Polycrylonitrile (Acrylic)
- Polyester
- Polypropylene
- **Nylon Staple**
Axminster Spool Weaving
Axminster Finishing
Gripper Axminster Carpet
Weaving of Gripper Axminster
Gripper-Spool Axminster Carpet
Weaving and Finishing of Gripper-Spool Axminster
Weaving of Chenille

Carpet Tufting

Summary
History
The Tufting Machine and its Operation
The Tufting Process
Elements of the Tufting Process
Supply Creel
Yarn Guide Tube
Beams
Yarn Joining
Air Splicing
Feed Rollers
Guides
Eccentric Shaft
Needle Bar
Reed Plate
Spiked Intake & Take Off Rollers
Presser Bar
Loopers
Knife
Primary Backing Fabric Roll
Gantry/Inspection/Perch
Faults and Corrective Measures
Formation of the Pile
Loop Pile
- **Pile Control Mechanisms** 83
  - Patterning Principles 83
  - Eccentric Cams on Yard Feed Rolls 84
  - Multi-Roll Feeds 84
  - Single-End Scroll-Type Attachment 85
  - Video Tuft 86
  - Universal Pattern Attachment 86
  - Mohasco Slat Attachment 87
  - Formation of cut and loop via single end scroll 87
  - Stitch Placement Mechanism 87
  - Sliding Needle Bar Attachments 87
  - Double Sliding Needle Bar 88
- **Combinations** 88
  - Hydrashift 88
  - Scroll Mechanism Computer Controlled 88
  - Hi-Fi (High Definition Cross Over Tufting Machine) 88
  - Card Munroe Precision Cut/Uncut 88
  - Colourtect 89
  - Tapistron 89
  - Servo Control 89
  - Yarn Retractor 89
  - Colorpoint 90
  - Level Cut Loop 91
  - Velv-A-Loop 91
Carpet Manufacturing

Colouring Tufted Carpets

- Differential Dyeing 92
- Fibre or Loose Stock Dyeing 92
- Hank Dyeing 92
- Space Dye Effects 93
- Package Dyeing 93
- Carpet Batch Dyeing 93
- Winch or Beck Dyeing 94
- Continuous Carpet Dyeing 95
- Carpet Printing 95
  - Stalwart Printing 96
  - Screen Printing 96
  - Splatter Printing 97
  - Foam Printing 97
  - Transfer Printing 98

Carpet Tiles

- General 98
- Tile Substrates 98
- Tile Backings 99
- Tile Cutting and Finishing 99
- Tile Patterning 100

Glossary of Carpet Terms

Conversion Tables
Carpets – Summary

What is Carpet?

Carpet is a soft textile floor covering produced by the insertion of fibre or yarns made from fibres, either natural or synthetic into a backing.

The surface of the carpet is referred to as the pile and may be cut or loop or a mixture of both. Numerous methods of manufacturing exist to achieve this end.

In Australia, carpet is generally manufactured in 366cm (144 inch) widths although 400cm (157 inch) is available. Some commercial or contract carpets are manufactured in narrow widths 100 cm (39 inch), 91 cm (36 inch) and 0.69m (27 inch).

Rugs refer to loose laid carpets, traditionally smaller than room dimensions and size.

Carpet offers great value, aesthetic beauty, comfort and warmth, thermal insulation and sound absorption.

Carpet is made to a predetermined specification based on end use.

Carpet Manufacturing Methods

Carpet is manufactured in a number of ways and the most used methods are:

(a) Tufting
(b) Weaving – Axminster and Wilton
(c) Modular carpet (tiles)

Other methods of carpet manufacturing are for example: bonded, flocked, needle punched.

Tufted and woven carpets are sold for domestic/residential and commercial/contract installations. Woven carpets traditionally form the high end of the market, while tufted carpets span the market from economy styles to high end. Modular carpets are used mainly in commercial installations.

History of Carpet

The construction of woven carpets is an ancient craft. In fact, the first woven carpets are thought to have been made about 5000 years ago. The basic technique of manufacturing carpet developed at that time (the technique of raising weft or warp to create a pile) is relevant today.

The early carpets were used as wall hangings as well as floor coverings. They were created in intricate patterns and designs which often reflected religious symbols. They were traded along the ancient trade routes of Asia and Europe, and many areas developed their own unique style.

The carpets of the Middle East were introduced into Europe by the Greeks and Romans as they expanded their empires. Craftsmen were encouraged to set up workshops in Italy, France and Spain.

Until the early part of the eighteenth century, all carpets were hand knotted to hold pile in place. This was a very labour intensive and slow process, so only the wealthy could afford to have carpets.
The French were the first to streamline the manufacture of carpets, in the south of France, at Aubusson and in the Flemish Lowlands.

In England, the carpet industry first developed in a town called Wilton. In the following years other carpet centres were established in Kidderminster and Axminster. By 1700 the carpet industry was well established and by 1830 there were 1100 looms in Kidderminster alone.

The invention of the Jacquard patterning mechanism in 1801 meant that the hand operated looms could produce a simplified ‘Persian’ style carpet much quicker than the original hand knotting process.

Power loom weaving was developed in the middle of the 19th century through the adaption of standard hand looms, and the first loom to be so adapted was the Brussels type. The introduction of steam power in Britain in the nineteenth century led to greatly increased carpet production rates, and with reduced cost of production. As a result, a far greater proportion of the populace was able to buy a carpet than was the case earlier.

As carpet making became more commercial, hand knotting declined, therefore the pile or nap became flatter. During the 18th century the raised pile became achievable through the Brussels loop, the forerunner of Wilton. The Axminster spool system, allowing unlimited colour use, came from an American invention in 1876, followed quickly by the Brintons Gripper.

Woven carpets were traditionally produced in ‘narrowloom’ 27 inches, (69 cm) and 36 inches (91cm). Twelve feet wide (366cm) broadloom machines were developed to reduce carpet installation costs and increase production efficiency.

The single most important factor in reducing carpet production costs this century has been the development of the tufting machine, which occurred in the 1950s. These machines have enabled much higher rates of production to be achieved than previously, and with reduced labour inputs.

This century has seen the development of specialised wool and synthetic fibres. These developments, together with improvements in carpet manufacturing and finishing techniques, have meant that carpet is now a major type of floor covering in residential, contract and commercial areas e.g. offices, schools, hotels.
Within the industry there is a wide range of manufacturing methods, carpet patterning and texture options. These are loop, cut, cut/loop, cut/cut (tufted), Axminster spool and gripper, Wilton and non woven, bonded and knitted. Many machines have sophisticated patterning devices with colouration produced by Stock or Fibre Dyeing, Hank Dyeing, Space Dyeing, Continuous Dyeing or Printing. A range of fibres - Natural and Synthetic (in pure form and in blends) are available in yarn form via the woollen and semi worsted system. Extruded filament and air entangled yarns extend the range of available options for broadloom carpets and tiles.

**Fibres in Carpets**

As carpet requires greater strength, resilience and abrasion resistance than most other textile products, the raw material for the pile must be chosen with these performance requirements in mind.

The pile is the face or top of the carpet and it must take the effect of wear. For centuries, wool was the dominant pile fibre and is still very popular. It has good abrasion resistance and is mildew, soil, stain and flame resistant. Overall, it has very good durability and appearance retention performance properties.

Synthetics are now the dominant pile fibres, either alone or as blends. The blend of 80% wool and 20% nylon has become a very common carpet pile composition. The blend is much more durable than an all-wool equivalent. In certain carpet constructions and textures, a blend of 60% wool and 40% acrylic may be as durable as the all-wool equivalent but less costly.

Carpets made with acrylic, nylon, polypropylene or polyester pile are difficult to wear out due to their resistance to abrasion characteristics. In certain conditions any fibre type carpet can generate static electricity as people walk across the carpet. However, carpets can be treated chemically or have static control fibres/yarns/backings/compounds included to eliminate this problem.

Carpets made from polypropylene, acrylic and polyester fibres have good abrasion resistance but tend to flatten more quickly than wool, nylon or triexta in similar structures. They are also more prone to soiling. Nylon pile carpets have excellent abrasion resistance and better recovery properties than the other synthetics.

**Carpet Textures**

Carpets have two main pile surfaces - cut pile and loop pile. Variations and mixtures of these textures are available in the global market place.
Choice of Fibre

In Australia, the major fibres used in carpets are nylon (polyamide), wool, polypropylene (polyolefin) and polyester.

There are also carpets made from a blending of the major fibres, for example: 80% wool/20% nylon; 80% wool/10% polyester/10% polypropylene.

While there are a variety of claims made by fibre suppliers, no one fibre necessarily makes a better carpet. Good quality carpets are made from quality materials and components, coupled with the skills of the manufacturer to produce a properly constructed carpet using these components.

For this reason, there is no simple answer to the ‘which fibre is best’ question and it is unwise for consumers to base a buying decision on fibre alone.

General Performance Characteristics of Fibres are shown in the following table:
## General Performance Characteristics of Fibres

<table>
<thead>
<tr>
<th></th>
<th>Wool</th>
<th>Nylon</th>
<th>Solution Dyed Nylon</th>
<th>Polypropylene</th>
<th>Polyester</th>
<th>Triexta</th>
<th>Acrylic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resilience</strong></td>
<td>excellent</td>
<td>excellent</td>
<td>excellent</td>
<td>very poor</td>
<td>poor</td>
<td>excellent</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Twist Retention</strong></td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
<td>excellent</td>
<td>excellent</td>
<td>excellent</td>
<td>good</td>
</tr>
<tr>
<td><strong>Abrasion Resistance</strong></td>
<td>fair</td>
<td>excellent</td>
<td>excellent</td>
<td>fair</td>
<td>good</td>
<td>excellent</td>
<td>fair</td>
</tr>
<tr>
<td><strong>Fastness to Light</strong></td>
<td>good</td>
<td>good</td>
<td>excellent</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
<td>good</td>
</tr>
<tr>
<td><strong>Fastness to Water &amp; Cleaning</strong></td>
<td>good</td>
<td>good</td>
<td>excellent</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
<td>good</td>
</tr>
<tr>
<td><strong>Fastness to Oxidising Gases</strong></td>
<td>fair</td>
<td>good (Type 6.6)</td>
<td>excellent</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
<td>good</td>
</tr>
<tr>
<td><strong>Stain Resistance</strong></td>
<td>fair</td>
<td>fair</td>
<td>fair</td>
<td>excellent</td>
<td>good</td>
<td>excellent</td>
<td>good</td>
</tr>
<tr>
<td><strong>Ease of Cleaning</strong></td>
<td>excellent</td>
<td>excellent</td>
<td>excellent</td>
<td>poor</td>
<td>fair</td>
<td>excellent</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Flammability</strong></td>
<td>excellent</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Static Electricity</strong></td>
<td>good</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
<td>poor</td>
</tr>
<tr>
<td></td>
<td>under normal conditions, poor under dry conditions</td>
<td>poor unless treated</td>
<td>poor unless treated</td>
<td>good</td>
<td>poor</td>
<td>poor unless treated</td>
<td>poor</td>
</tr>
<tr>
<td><strong>General Appearance Retention</strong></td>
<td>good</td>
<td>fair</td>
<td>fair</td>
<td>poor</td>
<td>poor</td>
<td>good</td>
<td>poor</td>
</tr>
</tbody>
</table>
Summary of the Path of Fibres/Filament to Floorcovering

Natural
- Wool
- Fibre
  - Source – Sheep
    - Greasy Wool Fibre
      - Scoured Fibre
        - White
  - White

Synthetic
- Polyamide
  - Fibre
    - Extrusion
      - Fibre
        - White
          - Dope Dyed
    - Filament
Polypropylene
  - Fibre
    - Filament
Polyester
  - Fibre
    - Filament

Wool & Wool/Synthetic Blends

Woollen & Semi Worsted Systems
- Yarn Formation**
  - Carpet and Tile Manufacture
    - Warehouse
      - Customer – Contract or Residential

Note: Yarn Formation**
see reference to Yarn Formation on following chart
Processing Path of Yarn to Floorcovering

The following processing chart provides the path of yarns as they make their way into finished broadloom carpets or tiles.
Carpet Grading Schemes

Carpet Grading Schemes have been designed to take a lot of the guesswork out of the carpet selection process. The best advice is to use the grading schemes to isolate the performance level or grading required and then let personal preferences rule the decision on the combination of fibre, colour, texture, handle and style.

The Australian Carpet Classification Scheme (ACCS) developed and administered by the Carpet Institute of Australia sets a full range of specifications for the grading of products, locally made and imported, composed of all carpet fibre types.

The Woolmark Carpet Classification Scheme and the Wools of New Zealand Carpet Grading Scheme are used by Australian Wool Innovations/The Woolmark Company and Wools of New Zealand respectively to grade pure wool and minimum 80% wool carpets.
Wool as a Carpet Fibre

For centuries, wool was the most widely used fibre for carpet pile. Today, synthetic fibres and filaments are more widely used. The range in carpet pile includes nylon, polypropylene acrylic, rayon, polyester and triexta. Wool and synthetic fibres are often used as blends. Some common blends are wool/nylon, wool/acrylic/nylon, wool/nylon/polyester, wool/nylon/polypropylene.

The use of wool as a pile fibre in carpet manufacture has reduced due to major advances made in synthetic yarn development, greater productivity achieved with filament synthetic yarns and the strong market for synthetic yarns.

However, wool continues to have a strong presence in the residential and contract market.

The carpet industry is the largest industrial consumer of wool in Australia, although this is mostly New Zealand wool. Small amounts of carpet wool are grown locally. Different styles of wool are produced by the various breeds of sheep. Large, heavy-bodied animals such as Romney or Drysdale will produce strong micron, long fibre suited to carpet manufacture. Fine micron wools are produced by the Australian Merino breed. There are a lot of crossbreeds producing a range of fibre types between these extremes.

Fibre Production

Wool grows from follicles in the skin of the sheep. After shearing, the greasy fibre is classed (separated into different styles of wool) and baled for transport to a scouring plant.

Scouring removes contaminants such as grease, suint (sweat products) and wax. Other acquired impurities such as vegetable matter (VM) will be removed during the carding or combing process. Heavily VM contaminated wool may need to be carbonised (treated with an acid solution) which burns the VM allowing it to be crushed to a powder and removed.

Wool Keratin

Wool is a protein fibre composed of amino acid monomers which collectively are called Keratin. It is generally accepted that 18 amino acids make up keratin.

Out of the thousands of proteins which are polymers of amino acids, only keratin and one or two others are fibre forming (i.e. Silk-Serecin).

Some of the amino acids in the keratin molecule contain sulphur and can form stabilising crosslinks between different polymers OR within different parts of the same polymer. These links are called the cystine lattice and this is similar to the process of vulcanisation which converts soft latex rubber to the hard, robust material used so widely. Silk is an example of a protein based fibre which does not have the sulphur crosslinks.
Fibre Structure

The strength of wool arises from the fact that the long keratin molecules lie alongside each other and are held together by strong hydrogen bonds, carbonyl (C=O) and amino (NH) groups in adjacent molecules. Covalent and electrostatic bonds also play a part.

In the relaxed wool fibre, the keratin molecules are folded or coiled and are referred to as alpha-keratin. When the fibre is stretched by steam, the molecules unfold and are then called beta-keratin. This is what gives wool its flexibility.

The para- and ortho- cortex run alongside each other forming approximately half the fibre each. The differences in elasticity between them cause the fibre to crimp along its length. This distinctive crimp is one of wool’s great properties as it provides great insulation and improves the ability to be spun into a yarn.
Fibre Characteristics

In the wool fibre, there are two forms of crimp - either ‘wave’ or ‘helical or corkscrew’. In general, fine micron fibres have a lot of crimp and strong micron fibres have less. Within the stronger micron fibre category, some carpet wools have little or no crimp (either wave or helical) while other carpet wool types have a well developed helical crimp – a benefit for setting of twist in yarns used in cut pile products. A fibre with high crimp can be stretched further than fibres with less crimp. This characteristic contributes to high elasticity in some wool types as it creates air pockets in and between the fibres which prevents cold air from penetrating and on hot days, these same air pockets will insulate from heat.

The fibre has good resilience and can be pressed down or compressed (i.e. walked on) and it will recover or spring back. Strong micron wool is ‘springier’ than fine micron wool.

It is hydrophilic (water loving) yet loses about 25% of its strength when wet. Wool is not strong when pulling forces are applied especially when the fibre is wet. This is because its polymer chains are not highly oriented.

The outside of the wool fibre repels water, however the inside of the fibre is very absorbent and wool is the most absorbent fibre in common use. ‘Bone dry’ wool will naturally absorb between 10% - 14% of moisture in the air and still feel dry. Wool will only feel wet after it has absorbed around 25% moisture.

In carpet, the yarn or pile surface can be treated to provide enhanced performance benefits such as static control to meet demanding contract specifications, soil & stain resistance and felting to produce texturing and less fibre loss during wear.

Greasy wool contains a range of contaminants that need to be removed. The processes that the wool can go through to remove these contaminants are scouring and carbonising.

The major contaminants in raw wool are:

- Wax, grease and lanolin - approximately 18% of total mass
- Dirt - approximately 6% of total mass
- Sweat/suint - approximately 6% of total mass
- Vegetable matter - approximately 5% of total mass

Dyeing

Wool can be dyed at many of the stages of production from raw material to carpet. A wide range of dyes are used, including acids,铬s, premetalised.

Wool can have colour applied at various stages throughout the production process as fibre, yarn or griege carpet. Wool carpet can be continuously dyed or screen and dye-jet printed as a wet process prior to lamination of the secondary backing.

If wool is usually dyed early in production processes, dyes must be chosen carefully, to withstand the rigors of the rest of the process.
Fibre Production and Processing Flowchart – Natural Fibre – Wool

- **WOOL**
  - Sheep – Greasy Wool
  - Scouring
  - Scoured Wool
  - Semi-Worsted System
    - Blending
    - Carding
    - Drawing
    - Spinning
    - Twisting, Hanking/Winding
  - Woolen System
    - Blending
    - Carding & Condensing
    - Spinning
    - Twisting, Hanking/Winding
  - Colouration of fibre & other other fibre treatments
    - Yarn Colouration, Scouring, Setting or Felting (Hank, Tube or Cone)
      - Yarn Rewinding, Axminster Spool Setting
        - Tufting
          - Colouration of Carpet
            - Carpet Tiles
            - Backing/Vulcanising
            - Cutting, Inspection, Packing
  - Contract
  - Residential

- Warehouse/Distribution
- Yarn Rewinding, Axminster Spool Setting
- Tufting
- Colouration of Carpet
- Carpet Tiles
- Backing/Vulcanising
- Cutting, Inspection, Packing
- Yarn Colouration, Scouring, Setting or Felting (Hank, Tube or Cone)
- Yarn Colouration, Scouring, Setting or Felting (Hank, Tube or Cone)
Yarn Production

Summary

There are two important staple yarn spinning systems used to produce yarns for the manufacture of carpet - the Woollen system and the Semi-Worsted system.

Their respective yarns can be described as:

- **woollen system** – good yarn bulk with a hairy surface
- **semi-worsted system** – less yarn bulk with a smoother surface.

The general rules for both weaving, bonding and tufting are:

- to use semi-worsted yarns in very dense carpet constructions where the compact nature of the yarn assists carpet pile formation and does not flatten readily
- to use woollen yarns in constructions where their bulk can be utilised to help the individual pile yarns support each other and where their matt appearance means the carpet does not visibly deteriorate as the pile flattens due to wear.

Other factors which are relevant in choosing between semi-worsted and woollen yarns are:

- **type of carpet to be produced**: for face-to-face carpet or fine gauge tufted carpet, semi-worsted would be favoured
- **availability of raw material**: the semi-worsted process requires better quality, cleaner and longer fibre length wools generally more expensive blends
- **twist and length set**: woollen spun yarns generally ‘set’ better than semi-worsted yarns, and have better cover due to their bulkier nature.

Semi-Worsted System

Staple fibres of between a length of 100 mm to 150 mm with a micron of greater than 30 micron are ideal for this system.

The semi-worsted system is based on the process used to produce fine yarn count wool worsted yarns for suitings but it has been shortened considerably to increase production throughput and efficiency.

As carding is included in the processing sequence, a combed wool input is not required.

**Blending**

The principles of blending remain the same irrespective of a single fibre blend e.g. all-wool, all-synthetic, or a multi-fibre e.g. wool blend, synthetic mix being prepared.

The raw materials are layered on a hopper feed sheet. The proportions are calculated and the different fibres/batches are layered accordingly. This blanket of fibres enters an opener/mixer via a spiked lattice. A combination of speed, spiked rollers and feed sheets move and mix the blanket of fibres to provide blending.
Air suction removes dust and short fibres and the blend is then blown to a feed bin behind the card (card bin). Lubricant is sprayed on the moving fibres as they leave the blenders to go to the card bin.

**Carding**

The card is fed by means of a large capacity hopper whose weighing mechanism is controlled electronically. To vary the input into the card, the size of the weigh can be adjusted or the frequency of the weigh can be increased or decreased. Deflector plates cause the weighed material to be dropped diagonally on the feed sheet so that when the material reaches the feed rollers two or more weighs can enter together. This action increases the mixing ability of the card and improves the uniformity of the sliver output of the card.

Around swift are workers and strippers. These are preceded by a breast section incorporating a series of licker-in rollers or feed rollers. Doffers clear the swift of material and these in turn are cleared by fly combs. The output (web) is consolidated into a loose fibre rope (sliver) and fed into a can.

**Drawing**

The process of drawing is undertaken usually with three intersecting gillboxes. Each gillbox has rows of pins which intersect the slivers. The new sliver formed is pulled through the pins by faster moving front rollers, so that straightening and drawing of fibres occurs.

The gilled sliver from passage 1 is then again combined with other slivers and re-gilled in passage 2, giving considerable mixing of fibres. The passage 2 slivers undergo a further gilling passage (passage 3 or finisher passage) to achieve maximum blending, fibre straightening and sliver evenness properties.

Autolevelling is used in gilling. Sensors speed up and slow down the speed of the gill delivery rollers to produce a sliver which is very uniform in thickness and weight per metre.

**Spinning**

Sliver is fed into the drafting system composed of a back draft zone between back roller and the aprons and a front draft zone between the aprons and the front delivery roller. The distance between the rollers and the tension rollers allows tension to be applied to the sliver fibres before they enter the drafting zone.

The object of the drafting zone is to draw the sliver to its required weight or linear density according to the yarn count required. This is the last point where the input sliver weight with appropriate draft applied to produce the required spun yarn count can be altered.

Pressure is applied to the top rollers in the drafting system, and ‘good spinning’ (acceptable yarn irregularity and ‘ends down’) is obtained by the relationship between the first and second set of rollers, this distance is known as the ratch and determines the regularity and count of yarn.

On leaving the front rollers, twist is inserted into the reduced sliver by the rotation of spindle and traveller that moves around the ring.

**Yarn Twist**

The twisting of a strand of fibres causes them to spiral tightly around each other, imparting strength to the strand of fibres (yarn). As the number of twists or turns per metre (tpm) or per inch (tpi) increases, the strength of the yarn increases.

Excessive twisting, however, produces a weaker yarn, as the fibres become so strained and spiralled that they break.
The amount of twist in a yarn influences not only strength but also other properties of the yarn. In fact, twist is the most important single factor that affects the yarn’s properties. The spinner uses a twist factor and the count of the yarn to calculate the turns per metre to largely determine the properties desired in the yarn.

More technical detail and explanation of yarn twist is explained in the woollen spinning section.

The yarn is wound onto the package by the action of the traveller lagging behind the spindle. It is important that travellers be of the correct weight to ensure the winding tension on to the tube or bobbin is suitable e.g. too lighter weight traveller produces soft packages and difficulties at twisting or winding while a too heavy traveller weight causes yarn breakage (effects yarn quality and package shape) and yarn hairiness.

Traveller weight affects tension on the yarn as it is wound onto the package, and considerable friction exists as the traveller moves at high speed (approximately 36 metres per second). Nylon travellers are used for high speeds together with good lubrication of the ring.

Twisting and Winding

Twisting is done on standard frames capable of high speeds and production of large packages. Each supply thread has a stop motion which, when activated, stops all supply to the particular spindle.

Twisting is followed by cone winding. Cone winding is used to transfer yarn from one package to another. While this process is taking place, any faults in the yarn such as weak spots, thick or thin parts are identified and repaired by a splicing process. Supply packages are tied top and tail (the thread at the ‘top’ or on the outside of the new package tied to the old thread at the ‘tail’ of the currently running package) to ensure continuation of yarn supply. Large supply packages permit extended running time of tufting.

Hanking

In preparation for hank dyeing, yarn is wound onto a reeling machine with a cross wound pattern that allows the assembly of yarns to be leased (leased – addition of band in figure 8 formation to aid rewinding). When the correct weight or length of yarn to suit the dye bath requirements is wound onto the reel and leased – leading and following ends tied off plus one or two figure 8 lease bands, the hank is removed from the reel ready for dyeing.

Summary of the Semi-Worsted System

Semi-worsted yarns can be used in cut pile, loop pile, Wilton woven and tufted carpets, and contract grade tufted carpets.

Characteristics of semi-worsted yarns are:
- stronger yarn with smoother appearance and better regularity
- higher production speeds
- less bulky yarns to provide pile surface cover
- need for more expensive blend (in the case of wool), to give suitable fibre lengths and colour
- extra attention compounding and backcoating is necessary to ensure adequate fibre bundle anchorage as well as tuft bind (and bond strength for tufteds).
Woollen System

As with the semi worsted system, any staple fibre of suitable length and diameter can be spun using this system.

Blending and Oiling

The aim of blending is to thoroughly mix the fibre and remove dust. The choice of different wools and fibres for blending is complex because of the large variety of types available, and the many different specifications required for end use products.

The actual process of blending is concerned primarily with the efficient mixing of the various types which go to make the yarn. This must be done thoroughly so that an even blend of fibres goes through the spinning process, and a uniform yarn is produced. The blending process is the same as that described for semi-worsted.

A modified mineral, water soluble or synthetic fibre processing lubricant is also added during the blending stage to minimise fibre breakage in carding and to assist in fibre movement in spinning. Modified mineral oils and water soluble synthetic oils are the most widely used.

Carding

Carding is the process of teasing apart and laying fibres roughly parallel into a 'carded web'.

Carding also removes vegetable matter that is present in the wool. These objectives are achieved by a number of different mechanisms.

The card is fed by a hopper (feed end) which weighs out a predetermined mass of fibre according to the required output from the condenser head (delivery or front end).

A carding machine consists of a number of units, with each comprising a series of rollers. These rollers can be the swift, doffer, fancy, angle stripper and a number of pairs of workers and strippers.
Each roller is covered with flexible wire or metallic card clothing and the action between any two rollers is dependant on the direction in which the card teeth point, the direction of rotation and the relative surface speeds of the rollers.

**Condensing**

The purpose of the condenser head on the front of the card is to convert the web of fibres combed from the last swift/doffer combination of the card by splitting the web into ‘individual ends’, drafting and then rubbing or condensing the end. This series of soft twistless ends or slubbings are wound onto condenser bobbins for the spinning process.

**Spinning**

The conversion from condensed slubbing to spun yarn is achieved by the application of draft and twist. Draft is the drawing out of the slubbing to a longer length, through the slippage of the fibres one over the other, while twist is the action of turning the yarn on its axis with one end held fast.

The twisting action binds the fibres together so slippage becomes increasingly difficult and eventually impossible, and gives strength to the yarn.

There are limits to the amount of draft and twist which can be inserted into any yarn. While the draft employed in woollen spinning rarely exceeds a factor of two, a stronger and more level yarn results from a higher draft (subject to the fibre length distribution within any individual end).

The amount of draft which can be employed in woollen spinning is dependant primarily on the quality, length and uniformity of the fibres in the blend. In drafting, the fibre movement is controlled by false twist generated on the spinning frame and, for successful operation, a correct balance between the false twist inserted and the amount of draft and the speed at which it is carried out is essential.

The most common type of woollen spinning is ring spinning. In this process, the roving is reduced in linear density as it passes through a drafting zone. The yarn produced is threaded through a traveller, or metal guide, free to rotate on a ring. As the bobbin or take-up package rotates, the traveller lags behind and the yarn is twisted and drawn onto the bobbin. The ring and traveller move up and down relative to the bobbin, distributing yarn on the bobbin.

**Twisting and Winding**

Twisting is done on standard frames capable of high speeds and production of large packages. Each supply thread has a stop motion which, when activated, stops all supply to the particular spindle.

Twisting is followed by cone winding. Cone winding is used to transfer yarn from one package to another. While this process is taking place, any faults in the yarn such as weak spots, thick or thin parts are identified and repaired by a splicing process. Supply packages are tied top and tail (the thread at the ‘top’ or on the outside of the new package tied to the old thread at the ‘tail’ of the currently running package) to ensure continuation of yarn supply. Large supply packages permit extended running time of tufting.
**Hanking**

In preparation for hank dyeing, yarn is wound onto a reeling machine with a cross wound pattern that allows the assembly of yarns to be leased (leased – addition of band in figure 8 formation to aid rewinding). When the correct weight or length of yarn to suit the dye bath requirements is wound onto the reel and leased – leading and following ends tied off plus one or two figure 8 lease bands, the hank is removed from the reel ready for dyeing.

**Summary of the Woollen System**

Woollen spun yarns can be used in all carpet constructions.

The characteristics of woollen spun yarns are:

- Yarns are very bulky and so improve the handle and cover of the carpet
- The carpet appearance does not deteriorate markedly as the pile flattens through wear
- Many special yarn effects can be created
- The yarns will achieve a higher level of ‘twist set’
- Shorter length and more variable quality fibres can be used
- When a clean, lustrous surface finish or appearance is required, woollen spun yarns tend to be hairier (more fibre ends protruding from the yarn surface is evident) and duller (lower light reflectance properties) than semi-worsted yarns due to their fibre orientation.

**Twist Factors of Woollen and Semi-Worsted Singles and Folding Yarns**

The role of twist factor, direction and amount of twist in tufting yarns and their relationship to the yarn count, machine gauge and tufting needle choice is often not well appreciated, defined or understood.

Carpet yarns are usually at the heavy end of the yarn count or thickness scale using higher micron fibres and lower twist factors than the finer yarn count apparel yarns. The appropriate level of twist of carpet yarns vary according to fibre length and texture required. Therefore, the final choice of twist level(s) is often made by the carpet manufacturer.

In order to assist determination of suitable twist levels, the Nomogram for Twist Factors of Woollen Spun Carpet Yarns shown on page 20 can be used to provide a direct reading for appropriate woollen yarn count (tex and metric), twist per metre (tpm) and twist factor (tex and metric).

The same nomogram can be used for semi-worsted yarns if the twist factors are reduced by 5% - 10% for singles and 3% - 10% for folding twist factor readings.

Providing that any two values are known, the third one is read directly on the incidence path of the other twist readings.
To provide guidance, the following descriptors for Ranges of TPM (turns per metre) and Table of Twist Factors can be used as a reference.

### Table of Twist Descriptors

<table>
<thead>
<tr>
<th>Descriptor of Twist*</th>
<th>Range of TPM (turns per metre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft Twist</td>
<td>40 to 140</td>
</tr>
<tr>
<td>Semi Hard Twist</td>
<td>141 to 216</td>
</tr>
<tr>
<td>Hard Twist</td>
<td>217 to 360</td>
</tr>
</tbody>
</table>

### Table of Twist Factors (Metric Unit) – determined via research project.

<table>
<thead>
<tr>
<th>Spinning System</th>
<th>*Twist Descriptor</th>
<th>Most popular values of Metric Twist Factor - Singles</th>
<th>Most popular values of Metric Twist Factor - Folding</th>
<th>80% of the yarns are within the range - Singles</th>
<th>80% of the yarns are within the range - Folding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woollen</td>
<td>Soft</td>
<td>95</td>
<td>92</td>
<td>70 - 115</td>
<td>75 - 112</td>
</tr>
<tr>
<td></td>
<td>Semi Hard</td>
<td>100</td>
<td>112</td>
<td>75 - 112</td>
<td>100 – 140</td>
</tr>
<tr>
<td></td>
<td>Hard</td>
<td>100</td>
<td>245</td>
<td>85 – 108</td>
<td>205 - 280</td>
</tr>
<tr>
<td>Semi-Worsted</td>
<td>Soft</td>
<td>70</td>
<td>90</td>
<td>55 – 87</td>
<td>78 – 110</td>
</tr>
<tr>
<td></td>
<td>Semi Hard</td>
<td>80</td>
<td>107</td>
<td>60 - 105</td>
<td>92 – 130</td>
</tr>
<tr>
<td></td>
<td>Hard</td>
<td>90</td>
<td>235</td>
<td>75 – 115</td>
<td>140 – 245</td>
</tr>
</tbody>
</table>
Nomogram for Twist Factors of Woollen Spun Carpet Yarns
If preferred and with a knowledge of appropriate twist factors, the levels of twist to be specified can be calculated.

**Turns per metre** = Metric twist factor multiplied by the square root of the Metric count

**Tex Count** = 1000 divided by Metric count

For example: A yarn has a Resultant Tex R620/2 i.e. 2 ends of Tex 288 twisted or folded together with an allowance of 7% for twist take-up.

**Folded yarn of Tex 620:**
- conversion to Metric Count = 1000/Tex 620 = 1.61
- chosen Metric Twist Factor is 87 for the folded (2 ply) yarn
- calculation for turns per metre (tpm) of the folded yarn is: 87√1.61 = 110 tpm

**Single yarn of Tex 288:**
- conversion to Metric Count = 1000/288 = 3.47
- chosen Metric Twist Factor is 85 for the singles yarn.
- calculation for turns per metre (tpm) of the singles yarn is: 85√3.47 = 158.3 tpm rounded to 160 tpm

**Twist Directions for Carpet Yarns**

For optimum efficiency and quality of tufting, there are major advantages, especially at high twist levels, in using the following twist directions.

<table>
<thead>
<tr>
<th>Cut Pile:</th>
<th>‘S’ twist in the singles; ‘Z’ twist in the folding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Pile:</td>
<td>‘Z’ twist in the singles; ‘S’ twist in the folding</td>
</tr>
</tbody>
</table>

If the yarn is to be used in the ‘single’ form then:

<table>
<thead>
<tr>
<th>Cut Pile:</th>
<th>‘Z’ twist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop Pile:</td>
<td>‘S’ twist</td>
</tr>
</tbody>
</table>

There are sound, practically established reasons for these rules. In the case of a yarn having an incorrect twist direction, the yarn loops generally tend to spring away from the looper, causing either a total missed looping action or split looping, i.e. the looper point embeds itself in the yarn. The higher the twist and the higher or heavier the yarn count, the greater will be this effect. In the case of a hard twist yarn, the effective build-up of incorrect twist will shear off the yarn from time to time, usually between the needle and the last guide fulcrum point. For weaving yarns, the directions of twist are generally standard at Z singles and S folding. So if an example of a weaving yarn is R620/2 the yarn specification can be stated as:

- Yarn Count: R620/2
- Singles Twist Level & Direction: 160 tpm ‘Z’
- Folding Twist Level & Direction: 110 tpm ‘S’
Felted Yarns

Development of techniques of yarn manufacture which exploit wool’s natural ability to felt have led to a highly wool-specific method of producing plain and fancy carpet yarns.

While it is true that methods of batch-felting hanks of carpet yarn have been available for some time, the process was not widely used due to the degree of inter-yarn entanglement and processing variability which made felted yarns less economic and practical than the commercial carpet maker would require.

Developments in aqueous and solvent batch-felting machinery have enabled carpet makers, especially tufters, to make greater use of woollen and semi-worsted felted yarns.

A continuous felting process, ‘Periloc’, can handle yarns, twistless worsted roving and woollen or semiworsted sliver and, can convert these inputs into highly efficient and attractive carpet yarns. In this process, it is not only possible to introduce nepes, slubs, flakes and similar but also an almost infinite number of combinations of yarns and sliver.

Felted yarns are often used in wider gauge carpet structures where their reduced fibre shedding and greatly improved tuft definition gives rise to the possibilities of new designs and textures as well as improved appearance retention and wear.

Treatment of Wool Carpet Yarns

After wool fibre has been converted to yarn, scouring is often needed to remove the fibre processing aids (lubricants) applied to assist in carding and spinning and to remove soiling materials which collect in and on the yarn during processing.

If the yarn is not scoured or if scouring does not reduce the residual or extractable matter to below a maximum of 1.0%, the carpet is likely to exhibit rapid and excessive soiling during floor trafficking.

If the yarn is dry spun, scouring may not be required to reduce the total extractable matter but within-mill ‘housekeeping’ must be of a high standard to avoid soiling the yarn.

Setting

Yarn setting is the process of inserting twist stability into a yarn in order for it to resist twist unwinding when the carpet pile is subjected to floor trafficking and wet cleaning.

This is a necessary process for wool yarns so that the carpet pile will maintain texture and tuft definition, both during processing and normal wear. Cut pile, winch dyed, continuously dyed or printed carpets require yarns with enhanced set characteristics to withstand high temperature exposure from the dyeing and wash off processes.

Various setting methods are possible, including autoclave setting, chemical setting, water setting and continuous setting.
**Autoclave Setting**

An autoclave is a vessel where the yarn may be treated with steam under pressure and in a vacuum.

A multi-cycle technique is required with this method and the process involves two or more short vacuum/steam cycles, with the vacuum being created initially in the autoclave to ensure that the steam fully penetrates the yarn, and the last steaming to carry out the setting. The final vacuum removes steam from the yarn and stops steam from entering the room after setting.

The conditions to achieve a good level of set on singles and folded yarns can be programmed. Woollen spun yarns are usually easier to set due to the entangled fibre orientation within the yarn. As semi-worsted yarns have a parallel arrangement of the fibres, they require crimpy wools in the blend to assist in achieving a necessary high degree of yarn set.

**Chemical Setting**

One method of chemical setting is to place hanks of yarn in a tape scour, with a sodium bisulphite solution in one or more stainless steel bowls and rinse off in subsequent bowls.

Chemical setting is accompanied by a slight bleaching and therefore yarns for printing are whiter in colour when set in this way. Berber yarns are increasingly chemically set because they are brighter in colour when compared to autoclave set yarns. Autoclaving generally causes some ‘yellowing’ to occur.

**Melt Fibre Setting**

Wool singles yarn can achieve a high level of twist set by incorporating 10%-15% of low melting point synthetic binder fibre into the blend and applying a heat treatment to the yarn. This causes the binder fibre to melt and collect where cross over points occur with the wool fibres.

The process eliminates the need for ply twisting and the resulting cut pile carpets have very good appearance retention and low propensity to shedding.
**Water Setting**

When a carpet yarn is hank or package dyed it is automatically set during the dyeing process. Similarly, treating yarn in boiling water either batch or continuous but not concurrently dyeing (i.e. referred to as water setting) was once a common yarn setting procedure.

Two such machine lines are:

- The Superba TVP machine (Superba S.A., Mulhouse, France) is a continuous autoclave and the resulting well set yarns can be used for stock-dyed Heather, Tweed, Berber in standard twist configurations as well as high twist or hard twist yarns.

- Chemset (ANDAR/WRONZ) now known as Twistset™ is for the setting of yarn in the form of a coil blanket. Processing is from package to package and during the process yarn scouring takes place slightly brightening the colour of wool. A very high level of yarn set is imparted with the yarn being suitable for most applications including the manufacture of piece dyed carpets.

**Continuous Setting**

All of the previously mentioned methods are batch processes with their inherent characteristics of inter-batch or within-batch and batch to batch differences and their higher labour and process costs. As a result, package to package yarn setting for carpet yarn was developed.
Insect Resist

Insect Resist (IR) Treatments
Fibres containing a protein, such as Keratin, are susceptible to damage by certain species of moth and beetle larvae, i.e. larvae from the common clothes moths and variegated carpet beetles, that have developed unique gut digestive systems allowing them to utilise keratin as a food source.

Fibres other than those containing protein may be damaged by insects trying to escape confinement and reach desirable food.

A similar situation arises when other fibres are blended with keratinaceous fibres.

Wool is the most susceptible and most frequently damaged fibre. Therefore, effective IR treatments need to be applied. Viscose can also be affected.

Application During Dyeing
Insect resist (IR) agents may be applied successfully in loose stock dyeing, yarn dyeing and carpet piece dyeing. IR agents applied during dyeing have better fastness properties than when applied by other methods.

However, yarns which are to be subsequently scoured are produced from loose stock dyed fibre, a small percentage of the IR agent may be removed during the scouring operation. As a consequence, the application level of the IR agent may need to be increased to compensate for the loss.

Application During Yarn Setting
If yarns are to be set in boiling water, an IR agent can be added to the setting bath in the same way it is added to the dyebath. Neutral or slightly acid conditions should be used.

Application in the Spinning Lubricant – this is not a recommended application option
If application of an IR agent to wool is made in conjunction with the spinning lubricant, poor IR fastness properties as well as human health issues will result.

Application from Solvent
Some IR agents are produced for application to wool specifically from dry cleaning solvent. If yarns are to be scoured or milled in a solvent processing machine, the agent may be applied after the milling process. The uptake of the IR agent can be affected by the amount of water and detergent or emulsifier used in the scouring or milling operation. Therefore, it is preferable to use a three bath process consisting of scouring/felting, rinsing, followed by IR agent application.
Static Control

Static build-up during processing appears to have become more of a problem with the increase in use of manufactured fibres. Within the processing environment, drier conditions linked to increased machinery speeds and heat build-up require greater control of static.

In addition to the difficulties encountered in production, static build-up can cause soiling of the carpet. Static build up in carpets leads to discomfort when a ‘charged’ person contacts an earthed object. Dry climates and low humidity conditions will cause static build up. Therefore, finishes, treatments or addition of static control measures need to be incorporated into the carpet structure.

Anti-static chemical finishes work by one or more of three basic methods.

- the finish may improve surface conductivity and thereby help the charge to move either to the ground or to the atmosphere
- the finish may attract molecules of water to the surface, which, in turn, increases the conductance and carries away the static charges
- chemical finishes may develop an electric charge opposite to that of the fibre which neutralises the electrostatic charges.

As fibre types differ in the type of static charge they generate (some positive and some negative), there must be specific finishing agents for different fibres for the third method to be effective.

Most chemical anti-static finishes are cationic surface active agents based on quaternary ammonium compounds. These finishes are not durable throughout the life of the carpet.

Non-chemical methods for static control are well established and include incorporating conductive carbon or stainless steel fibre in the blend. As an option, static control filament can also be added during the twisting process.

In some cases, depending on the level of static control required, conductive primary backing and carbon additives to the backing compound may be necessary. These methods work on the principle that any static build-up will immediately be earthed and dissipated.

Chemical treatments are available for addition at the fibre or hank dyeing stage and on-floor treatment can be carried out using the appropriate product. An example is the Disperstat™ range of products that work on the basis of stopping generation of static rather than acting as a conductor once static build-up occurs.

However, if Disperstat™ has been added to the fibre or yarn, care needs to be taken during application as over treatment can cause soiling during carpet use.

Anti-Soil and Anti-Stain Treatments

Four types of chemical finishes may be used to assist in maintaining the cleanliness of a carpet during its use:

- type 1 shields individual fibres by repelling oily soil
- type 2 assists in the release of oily soil absorbed in fibres and in finishes
- type 3 both repels and assists in releasing soil
- type 4 prevents staining from liquids containing anionic compounds.
Soil repellent treated carpets soil more slowly because water and/or oil bead up on their surface. Discoloured areas are prevented because the oils and water, plus any dirt or staining substances they may contain, can be wiped away before they have time to spread over the carpet or penetrate the surface. The soil is repelled by the treatment producing a smooth surface to which soil will not adhere. A charge repels the soil by producing a smooth surface to which soil will not adhere.

Soil repellents may be applied at the textile mill or as an 'after market' option. If the option is utilised, carpet warranty conditions need to be considered. Fluoropolymers, similar to those in non-stick cookware, 'surround' the fibres in treated carpet. They are strongly bound together and 'hook onto' the fibres. The fluorine shield strongly repels oil and water thus minimising contact between the oil and water, and the carpet.

Soil repellents work well on wool, nylon, polyester and acrylic carpets but are ineffective on polypropylene because of its oleophilic (oil loving) surface which has a natural attraction for oily substances.

Soil release finishing means that oily soil is more easily removed with cleaning. These finishes operate on one of two principles: (a) they encourage hydrophobic surfaces to release soil by making the surface more hydrophilic, which allows wet cleaning to more easily 'lift off' soil, or (b) they coat the fibres so that the soil never penetrates.

Many soil release finishes are nearly identical to soil repellent finishes. Chemicals used in soil release include fluorocarbons, acrylate emulsions and hydrophilic co-polymers.

During wet cleaning, soil repellent and soil release treated carpets resist soiling and readily release any soil that may adhere to the carpet pile. However, it is difficult to make a carpet both resistant to oily soiling and then be willing to release oily soils inadvertently embedded within it because directly opposite types of treated surfaces are required.

The enhancement of beading of water and oil demands a hydrophobic surface, whereas the release of embedded oil requires a hydrophilic surface.

The answer to this dilemma is a block copolymer, a polymer with two distinctly different parts that will change its orientation depending on whether it is in water or is exposed to air.

The fluorochemical (F) part gives the carpet soil resistance during use. The second part of the polymer is hydrophilic. In water, it gives the fibre/carpet pile a more hydrophilic surface and functions as a soil release agent.

The orientation of the polymer changes when its environment changes. After the carpet is cleaned and dried, the polymer is oriented with the fluorocarbon away from the fibre. In water, the fluorocarbon is toward the water.

Stain resist agents are used in conjunction with soil repellents to impart soil (oil) resistance and anionic stain resistance to nylon and wool carpets.

The stain resist agents for nylon carpets are sulphonated aldehyde condensation products which are believed to work by creating a negatively charged surface barrier on or near the fibre surface. This anionic shield protects the fibre from immediate staining or dyeing by anionic stains or dyes in food and drink, giving enough time for the spilled liquid to be wiped up before the staining compound attaches itself to positively charged sites in the carpet fibres.

Wool carpets can be given a treatment which gives greater resistance to staining by acid-based food dyes. The treatment covers microscopic fibre openings after dyeing and then a further coating again for lasting protection.
Man Made Carpet Fibres

Summary

There are two basic forms of synthetic fibre used in carpet.

- Staple (fibre like wool)
- BCF (nylon, polypropylene, polyester, acrylic and triexta).

Staple fibre synthetics are supplied in short fibre lengths that can be spun into yarns on the same equipment as used for wool or even mixed with wool to form a blended yarn.

The continuous filament yarns undergo a crimping process or bulking process that changes them from something thin and shiny (similar to a toothbrush bristle) to a softer, thicker yarn known as bulked continuous filament or BCF.

All this takes place in a continuous operation - polymer is melted, filtered, extruded under pressure, frozen back to solid form, drawn, bulked, lubricated and wound onto a package. All of this is continuously, automatically and closely controlled, limited in unbroken length only by the weight that can comfortably be handled by a machine operator in later processes - usually a package diameter of 250 mm and a weight of 7 kg.
Fibre Production and Processing Flowchart
Synthetic – Nylon (Polyamide)

- NYLON
  - Nylon Polymer Chip
    - Master Batch Colour Chip
    - Extrusion
      - White Nylon
      - Air Entangling
    - Creel or Beam
      - Twisting, Heat Setting, Winding
      - Creel or Beam
        - Carpet Formation
          - Greige Carpet
            - Colouration
              - Backcoating
                - Shearing/Cropping
                  - Cutting, Inspection, Packing
                    - Finishing, Inspection/Repair, Cut Length
                      - Warehouse/Distribution
                        - Contract
                          - Residential
Fibre History

Man made fibres are naturally long, thin with high strength and elastic recovery along their length. The most luxurious and sought after fibre early last century was silk, which was spun by the silkworm as a continuous filament, a very strong and elastic protein fibre, similar to spider’s web. Because of its great strength and fineness, silk was the fibre of choice for stockings and for lustrous beautifully draping fabrics. Its disadvantage was it was very expensive and available only to those people with high income.

It was not surprising that early chemists tried to make ‘artificial silk’ and they needed long strong molecules as building blocks. Viscose rayon was the first breakthrough using regenerated cellulose from wood pulp which was an existing fibrous molecule that could be extracted and recombined into long molecules. It could be extruded like silk into continuous filaments with high lustre and strength and was used in clothing and later, carpets until the 1950s. But the first truly synthetic fibre was invented in the laboratories of DuPont in 1935 by making a long molecule (polymer) from two shorter molecules (monomers) – the birth of nylon 6.6.

The molecule was held together by a chemical link called an amide link and as there were many (poly) of these along the length of the molecule, it was known generically as POLYAMIDE.

POLYAMIDE: The name NYLON was coined by DuPont for this new molecule and during World War II, nylon was in high demand because of its great strength and fine continuous filaments for slings, ropes, harnesses and parachutes during the conflict. It only became available for consumer goods after the end of the war. By the late 1950s nylon started to be used in tufted carpets (replacing viscose) as it had the advantage of very high abrasion resistance and recovery from flattening. It quickly grew in importance for carpet tufting and has since developed into a very versatile and easy to use fibre.

Nylon is produced in two quite different forms, nylon 6.6 and nylon 6. Both molecular chains are linked by the amide link but the building blocks (monomers) are different.

Nylon 6.6 has two different monomers, adipic acid and hexamethylene diamine. Each of these contains 6 carbon atoms and when they are linked together, the resulting polymer has a repeating unit containing 6.6 carbon atoms resulting in nylon 6.6. Nylon 6 however, is formed from one monomer (caprolactam) that also contains 6 carbon atoms and this combines with itself to form long chains with a repeating unit of 6 carbons. Although both are polyamides, they have different physical properties e.g. melting point and heat setting temperature, and dye absorption rates. During aqueous dyeing nylon 6.6 melts at 284°C and nylon 6 at 235°C so heat setting temperatures need to be adjusted to allow for this.

Nylon dyes are absorbed much faster into the more open structure of nylon 6 than nylon 6.6, and fastness and staining properties can be different. The extrusion of nylon 6 is less technically demanding and a number of major carpet mills around the world have installed nylon 6 extrusion capacity.

In comparison, Nylon 6.6 (invented and pioneered by DuPont) requires closer control over polymer conditioning and is only extruded by a small number of companies, very few of which are carpet mills.

Nylon filaments are formed by forcing molten polymer under pressure through a filter and a steel plate or spinneret in which precisely designed holes have been laser cut, each hole producing one stream of molten polymer that will become a continuous filament of nylon.
A continuous filament yarn will typically contain 70 filaments (the spinneret contains 70 identical holes) which are gathered together after cooling, conditioned, drawn (to align the polymer molecules and give maximum strength), bulked and wound onto parallel tubes.

Polymer characteristics can be changed in several ways, firstly by the polymer chemistry, to increase or decrease the dye – ability of the yarn, or even to make the yarn accept a different type of dye (called differential dyeing and important for producing patterns and heathers in piece dyed carpets). Secondly, the viscosity is regulated to control polymer length, crystalinity and carpet performance.

Fibre lustre can be modified by adding delustrant - Titanium Dioxide (TiO2) to the polymer. Modified carpet appearance and performance can be engineered by changing the cross section of the filament, including square hollow (maximum performance in heavy use contract) and more commonly, long-lobed trilobal (for maximum bulk and soft feeling residential use).

The cross section shape is achieved by the shape of the spinneret hole and the speed of the filament cooling, e.g. trilobal filaments are produced from a Y shaped hole. As an alternative to making white, dyeable fibres, colour can also be added at this stage. This is solution dyeing (SDN) resulting in high light fade resistance.

By changing the decitex of each filament, the carpet feel can be changed from harsh (22 decitex for contract installations) to very soft (3 decitex) for bath mats. In carpet use, nylon is strong, easy to tuft, resilient, highly resistant to abrasion, easily coloured, versatile in design and use and is also readily recycled, usually into car components.

**POLYACRYLONITRILE (ACRYLIC)** was invented in USA in 1956 and was popular in tufted carpets because of its soft handle characteristics until the mid 1970s when the ease of dyeing of white nylon carpet in piece form gave nylon an advantage in the USA. It is mainly used in Japan and some mid eastern countries.

**POLYESTER** (Polyethylene Terephthalate) was invented in UK by Calico Printers Association in 1942 and developed there by ICI as “Terylene TM” (Type 1). Generally referred to as normal polyester, it has very good resistance to ultra violet becoming the fibre of choice for drapes. As it readily achieves an almost permanent set, it is usually blended with wool for crease resistant suiting.
This type has a market niche in USA as a residential heavy weight cut pile carpet yarn. Its use in carpet has been limited because of its low resilience and need to be dyed under high pressure but it is used in heavy pile weight residential carpets (it has good stain resistance) and for automotive floor covering.

More recently a different form of polyester (Type 2) known as PTT. or 3GT has re appeared although its invention also dates back to the late 1940s. This polyester has the ability to accept dyes at normal pressure but it is significantly more expensive than so-called 'normal' polyester.

- **Type 1:**
  The fibre is extruded, cut into short lengths of 150 mm - 170 mm and spun into a yarn followed by heat setting.

  This polyester type needs to be dyed at high temperature because its polymer structure is a closed matrix, difficult for even small molecule dyes to penetrate without more energy than available at boiling temperature. Polyester therefore requires pressurised dyeing equipment to enable the temperature to be raised to 120°C.

  In USA, this is either fibre dyeing in pressure vats or carpet piece dyeing in pressure dye ‘becks’ and ‘jets’.

  These machines have not been installed in Australia so little polyester is used.

  As it is also fibre dyed, it is used for blending with wool in China where its excellent heat setting ability produces blended yarns with good tip definition in cut pile carpets.

  In use, polyester carpets have excellent resistance to water borne stains but as with polypropylene, poor resistance to oily stains and soiling. As it has low recovery from flattening by foot traffic, the most successful carpets are usually heavy weight cut pile styles used in low traffic residential installations. Its use in level loop pile products has been limited due to its low abrasion resistance.

  This form of polyester is widely used in soft drink (PET) bottles. Recycled polymer from collected bottles is extruded in USA into both staple for yarn spinning and BCF carpet yarn. In some BCF production, it is extruded as a solution dyed product, avoiding the need for high temperature dyeing.

- **Type 2:**
  Invented around the same time as Type 1, 3GT or PTT polyester has a modified polymer structure that is more open, allowing dyes to penetrate more easily. 3GT can be dyed using conventional, non pressurised equipment and the same class of dyes, as used for nylon. This has made 3GT attractive as a carpet fibre but its cost compared to nylon and its ‘in-use performance as polyester’ has restricted its introduction. However, interest has been renewed as the raw materials available from modified maize give an environmentally sustainable aspect to 3GT.

  A commercially available PTT fibre is TRIEXTA. It is stronger, with better colourfastness and cleanability features than PET. PTT is as colourfast as solution dyed nylon. The fibre is extremely soft yet it behaves better than staple nylon, especially in a shag pile construction. PTT is just one step away chemically from 4GT polymer that is used to make tough automotive parts.

**POLYPROPYLENE** (also known as polyolefin) is polymerised from propylene gas, readily available and easily formed into linear polymers suitable for fibres. Invented in Italy in 1956, it was slowly developed for carpet in the USA and Europe during the late 1960s and 1970s. It is extruded through spinnerets from molten pre-coloured polymer as it cannot be dyed by conventional means using water-borne dyes.
Polypropylene is lipophilic (oil attracting) and hydrophobic (water repelling). This leads to some good performance characteristics as polypropylene resists water borne stains and is quick to dry as well as some characteristics, not so good e.g. polypropylene is almost impossible to clean if oil or fat is present.

It has a much lower melting temperature of 135°C which may result in damage to carpet when heavy furniture or even shoes are dragged across the carpet pile creating heat from friction.

While it is very strong, polypropylene has low resilience and must be used in adjusted constructions to overcome this disadvantage, such as high density, low profile loop pile carpet although it is used in the cut pile constructions of greater than 1500 g/m² total pile mass and woven face to face runners, mats & rugs produced for use in residential installations.

As it is coloured via pigment addition to the molten polymer, polypropylene has very high light fade resistance and is used in outdoor carpet and synthetic grass on sports fields.

Globally, Polyamide, Polypropylene and Polyester are the three synthetic carpet fibres in regular use. Although these fibres are all synthetic, they vary in their properties and the way in which they are used. Therefore, it is necessary to differentiate between two basic colouration methods for carpet yarns and between two basic fibre formats.

Traditionally carpet fibre has been supplied to the yarn spinner as a white fibre to which the colour is applied either in fibre, yarn or carpet form. This applies to wool, viscose, acrylic, nylon and polyester. When polypropylene became available, it needed to be coloured by adding pigments to the polymer before the polymer was extruded into fibre. This has become known as ‘Solution Dyeing’. More recently, this method of colouration is also applicable to polyamide and polyester.

Unlike yarns from natural fibres which rely on inter-fibre friction and twist to give them strength, synthetic yarns are mostly BCF, composed of continuous filaments and do not need twist for strength. As a consequence, twisting of synthetic yarns there is more a styling tool e.g. for mixing colours of solution dyed yarns.

Unlike yarns from natural fibres which rely on inter-fibre friction and twist to give them strength, synthetic yarns are mostly BCF, composed of continuous filaments and do not need twist for strength. As a consequence, twisting of synthetic yarns there is more a styling tool e.g. for mixing colours of solution dyed yarns.

If the yarn is to be used in cut pile, rather than loop pile, then the twisted BCF will also need to be heat treated to set the twist and discourage the twisted yarn from unravelling during carpet use. Different BCF yarns can also be mixed and formed into thicker yarns, by entangling the filaments together through an air jet, and this type of heathered yarn is generally used in loop pile styles for contract carpets.

Solution dyed non heatset singles yarn with crimp

Traditionally carpet fibre has been supplied to the yarn spinner as a white fibre to which the colour is applied either in fibre, yarn or carpet form. This applies to wool, viscose, acrylic, nylon and polyester. When polypropylene became available, it needed to be coloured by adding pigments to the polymer before the polymer was extruded into fibre. This has become known as ‘Solution Dyeing’. More recently, this method of colouration is also applicable to polyamide and polyester.

Unlike yarns from natural fibres which rely on inter-fibre friction and twist to give them strength, synthetic yarns are mostly BCF, composed of continuous filaments and do not need twist for strength. As a consequence, twisting of synthetic yarns there is more a styling tool e.g. for mixing colours of solution dyed yarns.

Unlike yarns from natural fibres which rely on inter-fibre friction and twist to give them strength, synthetic yarns are mostly BCF, composed of continuous filaments and do not need twist for strength. As a consequence, twisting of synthetic yarns there is more a styling tool e.g. for mixing colours of solution dyed yarns.

If the yarn is to be used in cut pile, rather than loop pile, then the twisted BCF will also need to be heat treated to set the twist and discourage the twisted yarn from unravelling during carpet use. Different BCF yarns can also be mixed and formed into thicker yarns, by entangling the filaments together through an air jet, and this type of heathered yarn is generally used in loop pile styles for contract carpets.
Nylon Staple

Nylon fibres can be spun on the same equipment as other fibres such as wool or acrylic, either as 100% or in blends. The fibres are available in different lustre types (bright to dull), cross sections, fineness (denier, decitex), crimp and length. These variables will determine the feel, appearance, performance and spin-ability of the yarn and should be chosen carefully.

Soft feel is achieved using fine decitex (below 10) fibres and these are used mostly for bathmats and rugs. Higher decitex (above 20) fibres are used for cut pile contract carpet, and the in between (10 – 18) decitex fibres are used mostly for residential products. When designing a yarn, the number of fibres in the yarn bundle must also be considered and should be a minimum of 70 otherwise uneven spinning will result. Therefore, the fibre decitex and yarn count must be considered together.

Spun nylon yarns should not be used for loop pile constructions, either in 100% or blends, as the strength and high abrasion resistance of nylon prevents any loosened fibres from wearing away from the carpet surface, resulting in an unacceptable web of fibre developing over the carpet surface during wear.

Spun nylon yarns must be heat set for best performance in cut pile constructions. Heat setting needs to be done at elevated temperatures in dry heat (Suessen machine) or in non superheated steam under pressure (autoclave and Superba machines).

- **Autoclave** - multiple cycle with vacuum before steam injection to remove all air. Setting temperatures should be 126°C for nylon 6, and 132°C for nylon 6.6
- **Superba** – same setting temperatures as above
- **Suessen** – dry heat machine, temperatures should be 180°C for nylon 6 and 205°C – 210°C for nylon 6.6

Spinning of Nylon Staple

Like wool, nylon can be spun into yarn before dyeing or more usually, after loose fibre dyeing. It is vital that a suitable lubricant is added to the nylon fibres after dyeing and it is sometimes just as helpful for un-dyed fibre, as nylon has a very high fibre to fibre friction.

Most nylon is spun on semi-worsted equipment and although little adjustment is needed from wool settings, the high fibre friction means that fibre drafting needs to be done gradually. During spinning, dual zone drafting and long draft zones are preferable.

Antistatic fibres can be added if necessary. In some branded fibres, antistatic control has already been included by the nylon manufacturer.

BCF Twisting (Cabling)

The machine typically has 60 spindles on each side, spaced 400 mm apart. Over the machine is a drop down creel on which two supply packages are loaded (one active, one reserve).

The spindle is a flat plate like disc drilled with a hole through from the edge to the middle to act as a yarn path. This spindle plate is rotated at 5,000 - 7,000 rev/min by a belt through a clutch and brake. Over the spindle plate but not rotating with it, is an aluminium can into which a supply yarn is placed. Over this fits a conical cover, at the apex of which is a tension control.
The creel yarn is fed down through tensioners, guides and under the spindle plate. The yarn is fed through the hole in the plate and out to the rim, round the outside of the can and up to the top guide where it is joined by the yarn from the can and fed directly upwards through the conical can cover and tensioner.

The two yarns (can and creel) come together after the top guide and are pulled through the spindle assembly by the take up roller, through a traverse onto a tube. As the spindle plate rotates it takes the creel fed yarn with it creating a balloon around the can. In this way the creel yarn is wrapped around the can yarn continuously. By adjusting tensions, the twist can be balanced. At 5,000 rev/min of the spindle, and 160 tpm inserted twist, the yarn speed is 320 metres per minute, for each spindle.

Once the yarn in the can has run out, the machine is stopped and this yarn replaced, limiting the maximum twist package weight to twice the supply package weight. Creel yarn is tied tail to nose (top).

**Heat Setting - Superba**

The preferred heat setting method depends on the polymer. For polyester and polypropylene, dry heat is recommended but for nylon the most effective twist set is obtained by using a saturated steam medium at high temperature, the steam needed to break and reform internal molecular bonding.

Two continuous machines are used, Superba (saturated steam) and Horauf-Suessen (hot air). As nylon is the bigger usage fibre and because most polypropylene is used in loop pile and not heat set, the Superba is the most widely used machine for heat setting synthetic carpet yarn.

The machine was developed by Superba in the 1970s and not only greatly increased productivity compared to the existing autoclave process but also improved yarn uniformity and dye-ability, contributing to the use of BCF nylon in solid colour piece dyed carpets. The machine is a continuous package to package autoclave and is fed with yarn from a creel (the take up packages from the cabler described previously). Finished yarn on package is ready for tufting into carpet.
Heat Setting - Horauf-Suessen

In this process the yarn is fed from the creel through a coiler that winds it around 4 slowly moving Kevlar® ropes which transport it into the heat setting oven. The heat setting is done by hot air e.g. usually 190°C for nylon 6.6 and polyester. Superheated steam is injected to reduce oxidation of the yarn and assist heat transfer. Like the Superba, this machine is a package to package unit.

Air Entangling

This important process is used for mixing together BCF yarns of different colours as well as adding texture to the yarn. It is often referred to as ‘Heathering’ or a means of producing a ‘heather mix’. The process involves drawing two or more (up to 8 BCF yarns can be combined) through an orifice into which high pressure (6-8 bar) air is injected. The air disturbs the individual filaments of the BCF yarns and mixes them together. Tension, yarn speed and air pressure are the key variables.

Dyeing Nylon

Nylon polymer has free amine (NH2) groups at the ends of the polymer chains that in acidic solutions become positively charged. In this condition they will attract negatively charged dye molecules. All dyeing of conventional ‘white’ nylon depends on this. The negative dyes are acid dyes, so called as they need acid conditions to dye the fibre and usually contain one or more sulphonate groups.

This basic chemistry is used in two different types of dyeing processes:

- Batch dyeing where the nylon is immersed in water and the temperature raised to boiling. Several types of equipment exist to colour either loose fibre, yarn or carpet already tufted
- Continuous dyeing and printing where the dye is made into a thickened paste and spread over the white carpet (or sometimes yarn) either to give one solid colour or in areas of different colours to form a pattern (printing).

In all dyeing methods, the aim is to get even distribution of dye through the fibre, yarn or carpet and to achieve full penetration (inner and outer layers) of the dye into the nylon polymer. The following dye methods have been developed accordingly.
Selection of the correct dyes to use is important not only for economic reasons but also to achieve a dyeing with adequate fastness standards.

Most carpet colours are achieved by mixing yellow, red and blue dyes, all of which must dye the nylon in the same way under the given conditions (the dyes need to be compatible).

As much of the carpet sold in Australia is beige or a beige variation, and beige is about 90% yellow (with the rest red and blue), the cost and colour yield of the yellow is very important.

In some markets such as Europe and Japan, dye variant nylons are used to make multi coloured carpets (usually loop pile heather) from white carpet in a single dyeing operation. This is achieved by altering the chemistry of the nylon 6.6 polymer and adding negative charged dye sites that will repel negative dyes (acid dyes) while attracting positive charged dyes (cationic or basic dyes). The degree of acceptance into and onto the fibre of either dye class is also varied and up to 4 different shades or depths of the same shades can be obtained, enabling many colour styles to be offered from one tufted base cloth.

**Batch Dyeing of Nylon**

In general, when processed yarn or carpet is dyed in individual batches or lots, they must be kept separate due to colour variation between batches. The exception is loose stock dyed fibre where a number of individual batches can be blended to provide greater shade uniformity.

**Loose Stock or Fibre Dyeing**

Short staple fibre is packed down tightly into a stainless steel perforated cage which is immersed in boiling dye solution in an outer stainless steel vat. A pump circulates the solution through the fibre until all the dye has transferred from the solution into the fibre. Throughout the vat, a reasonably consistent packing density of the fibre is essential to get an even flow of the liquor to achieve a level dyeing.

**Hank Dyeing**

The white yarn is wound into hanks and the hanks suspended in rows on rods and immersed in boiling dye solution which is continuously circulated by a pump.

**Carpet Piece Dyeing**

Referred to as Beck Dyeing (USA) or Winch Dyeing (UK). The tufted white carpet is joined end to end to form a continuous band loosely round a slowly rotating drum in the beck/winch. The bulk of the carpet is immersed in a dye solution situated below the drum. The dye solution is slowly raised to boiling while the carpet is moved through it by the rotating drum. If the carpet style is cut pile, it can be allowed to bunch up into a rope but for loop pile styles, the carpet must be kept at open width, achieved by a spreader roller at the front of the machine. Up to 400 lineal metres of carpet can be dyed in one batch in a single machine.

Dye solution pH (acidity), final temperature and rate of temperature increase must be carefully controlled in all dyeing methods to get repeatability of colour.
Continuous Dyeing of Nylon Carpet

Smaller operations will use beck/winch or yarn dyeing and due to its colour uniformity, loose fibre or stock dyeing is preferred for special end use contract installations.

As continuous dyeing equipment is both expensive and large, only mills with high production levels of nylon are likely to have this technology and it is the most frequently used method of colouring or dyeing white nylon carpet.

In this dyeing process, the acid dye is dissolved in water, thickened with gum, otherwise water only then spread evenly over the griège surface pile of the carpet.

The most common applicator for the dye solution is made by Kuster (Germany) and known as a Fluidyer, which is a narrow slot positioned just touching the carpet surface through which the dye is pumped at a controlled rate. The contact between the Fluidyer slot and the carpet surface is controlled by air pressure in a bellows beneath the carpet.

The correct shade is achieved either by:

- premixing different dyes together before they are pumped to the applicator, or
- drawing liquid dyes individually from supply drums to the head under carefully metered conditions controlled by a software programme.

*Schematic of a continuous dye line*
Specialty Carpet Manufacture

The specialty carpet manufacturing methods include both the traditional hand knotting method and the non woven methods of needle punching and melding (flocking).

Hand Knotting

Hand knotted carpets were made by nomads centuries ago and are still made today, commercially and in the craft field.

A warp bed is made on a beam, creel or over some dividing sticks. Refinements such as a simple reed can be incorporated to keep the warp threads separate and operate the shed - the raising and lowering of the sets of yarn.

Pre-cut pieces of yarn are tied round the warps.

A weft thread or two is passed across and beaten against the previous line of pile with a large toothed comb, the shed changes and the process is repeated.

Normally the loom is upright, in that, the warps run from the floor upwards so the weaver is facing their work vertically.

It is the classic weaving principle, all operated by hand.

Many finishing techniques can follow. For example: the carpet can be cold washed and rubbed to give sheen or it can be felted or scissor sculptured.

The best examples of hand knotted carpets are the ever present Persians, Chinese and Indian types.

European Carpet Styles

There were also a number of different styles of European carpets which include:

- Aubusson – a style of hand woven rug, similar to a tapestry. Around the year 1600, it was being manufactured in the Flemish town of the same name. The cloth was woven sideways, from left to right, or warp wise to the usually intricate florals design.

- Savonnerie – a style created in France in 1620. The pile fabric was woven from bottom to top, and rows of knots were tied over a sharp-edged iron rod extending across the loom. The loops were cut when the rod was withdrawn. This principle was later adapted to produce the Wilton carpet.

- Ingrain carpets – also known as ‘Kidderminster’ or ‘Scotch’ carpets. They are a reversible double-cloth with flat, slightly ribbed surfaces similar to hand-woven tapestry. The pattern is created by addition of a jacquard mechanism. A reverse version of the pattern appears on the back of the carpet. These carpets were woven on a ‘Plain Loom’ which is no longer manufactured.
Knitted Carpet

Carpet has been produced on both warp-knitting and weft-knitting machines.

The pile yarn and the backing are fabricated in the one operation, unlike tufting which inserts the pile in a pre-formed substrate.

Knitted carpets are usually backcoated and given a secondary backing the same as tufted carpets. However, because of their structure they may be inherently dimensionally unstable and tend to stretch excessively.

Another problem with knitted carpets is the diagonal staggered stitch, which makes it difficult to create neat cross seams.

Design possibilities are also restricted compared to most other carpet manufacturing methods.

Bonded Carpet

There are many variations on this basic principle of bonding pile fibres or yarns to a supporting fabric base and the process of bonding offers:

- greater use of pile yarn/fibre
- single, self contained machine
- use of shorter fibres
- singles yarn rather than folded yarns
- no secondary backing delamination
- high output efficiency
- limited design capability other than via dyed yarns and effect yarns.

**Bonded carpets with yarn as an input:**

- **Vernier** – the process is similar to the Neko Process but uses molten adhesive which solidifies on cooling. The appearance of the final carpet is similar to a plain cut pile Wilton

- **Couquet** – this process is also similar to the Neko process but involves the application of a heavy layer of molten plastic to each surface of the crimped pile prior to slitting. No backing fabric is applied.

- **Stitch Bonded** – carpets where the structure is a fibre web bonded by stitching yarns. This product has ‘clumps’ of fibres which create the wear surface.
- Spun Bonded – carpets where the processes of fibre extrusion and fabric formation are combined. It is also used to produce primary backings for tufted carpets.
Karvel Process

This is an early type of bonded carpet. A carded batt of fibres is formed into a corrugated sheet of a required thickness. It is carried by a conveyor to the surface of a large metal drum with small grooves to accommodate the ridges of pile created by the corrugations in the pile sheet. The inserting head forces the pile into the ridges. The pile is sprayed with glue and brought into contact with a pre-coated backing material under tension.

The drum is heated in order to cure the adhesive and good adhesion occurs between the pile batt and the backing. The pile may be left as ridges of loop pile or sheared by the cutter to create a cut pile.
**Neko Process**

While this process is similar to the Karvel process, two fabrics are created face-to-face. The bonded sandwich of pile batt is then slit to create two pile cut carpets.
**Flocked Carpet**

Flocked carpet is a type of bonded carpet where individual fibres are embedded end-on into a backing cloth which has an adhesive coating on its upper surface. The backing cloth is drawn over a plate that contains one electrode of a high potential electrical system. A hopper containing the flock is placed over the plate. The sieve in the base of the hopper forms the opposite electrode. Fibre flock is sifted through the sieve or grid where it receives an electrostatic charge. The fibres are then projected end-on into the adhesive and penetrate the adhesive layer. The length of the fibre is generally limited to 2mm-3mm.

Due to their common electrostatic charge, the fibres mutually repel each other, and distribute themselves evenly. Excess flock is removed both electrostatically and pneumatically. The carpet is then dried, cured, cooled and brushed.

**Needle Punched Carpets**

There are two basic types of non-woven fabrics, chemically bonded and mechanically bonded. Needle punching is the main method of producing mechanically bonded fabric. This process is also known as needle-felting or needle-bonding.

There are two types of needle-punched fabric: those produced from the web alone, and those incorporating a woven backing fabric, either as a base or sandwiched between two needled layers.

The high rate of production of needle-punched fabric and elimination of spinning, enables needle-punched carpets to be produced at relatively low cost.

The stages of production of needle-punching are:
- Web formation
- Consolidation
Web Formation

The creation of the fibre web is the first stage of production. The web forms the carpet pile and can be made of any of the pure fibres or fibre blends.

The fibrous web is usually made on a non-woven card. The carded web is delivered by a lapping device. Cross laid webs are produced by means of a cross-lapper which takes web from the card and traverses it across a moving bottom lattice, thereby building a web in which fibres lie diagonally across the width.

The web can make multiple passes across a single card to build the required web thickness, or more commonly, the output of two or more cards is combined.

The quality of the final carpet depends on the regularity of the web. Cross oriented webs have high strength in both the lengthwise and widthwise directions.

Random webs which have no particular direction of fibre orientation are created by ‘air laying’ techniques rather than cross-lapping.

Consolidation

Manufacture consists of reinforcement and consolidation of the fibrous web by the reciprocation of barbed needles repeatedly penetrating the web so that the material becomes matted and decreases in thickness.

Generally, the needle beam reciprocates and moves the needle loom up and down. The needles are fixed to this board and oscillate vertically on a fixed stroke through the web which is supported between the two plates. The plates are drilled with holes to match the pattern of needles in the needle board.

The loom may be one of a series of single board looms. Multi-board looms increase the density of needles that can act on the web during a single passage. Needles can also act from above and below at the same time to increase efficiency.
There are also four board machines that have four double sets of needle boards. The upper and lower needle boards can operate simultaneously or one after the other. The upper and lower needle boards are offset so that they do not clash with each other if operated simultaneously.

The size of the needle, shape of the needle point and the number and size of barbs on the needle used, are varied according to the characteristics of the raw material and on the desired product. Increasing the amount of needling (up to an optimum level) increases carpet strength, density, elastic recovery, stiffness and abrasion resistance. Thicker webs consolidate quicker than lighter weight webs.

As the needle passes through the web, the barbs snag some fibres and carry them down then orient them through the web. Continued needling entwines, compacts and intermingles all the fibres in the web.

Some problems can occur with the quality of the needle punched carpets and these are:

- a regular lay-out of needles in the needle board can create an unwanted patterned effect in the carpet pile, rather than a desired random effect
- worn or unsuitable needles may break an excessive amount of fibres, rather than punching them through the web. This will decrease the strength of the product and will lead to inefficient production time.

---

**Wilton Carpet Manufacture**

**Brussels Carpet**

The Brussels carpet led to the Wilton carpet. The Brussels or Tournai style of carpet was produced from as early as the fifteenth century. By 1720, it was produced on a treadle operated horizontal loom. The Brussels carpet is a loop pile carpet with a pile yarn warp and a jute stuffer and weft.

The pile is formed from spun yarns which run warp - wise in the same direction as the chain warp and stuffer yarns.
The simplest Brussels carpet has a single coloured pile which is supplied to the loom from a pile beam. However, up to six colours can be woven on a six frame loom with jacquard attachment where the yarns are supplied to the loom directly from yarn cones which are mounted on a series of (up to) six frames or creels.

Even though Brussels is a forerunner of the Wilton carpet weaving method, Brussels looms only produce loop pile carpets. Wilton looms can create either loop or cut pile, or a mixture of both.

Brussels carpet is woven in the same way as a Wilton, with pile being formed by weaving the pile yarns over a pile wire which is later removed.

Unlike Wilton carpets, however, there is only a single top shot and a single bottom shot in the fabric weave. This means that Brussels carpets generally achieve lower tuft bind or tuft retention.

Wilton Carpet

In 1740, Brussels carpet was made in Wilton, England. In 1741, a patent was awarded for a blade to be incorporated into the pile-forming wire so that the pile loops would be cut on withdrawal of the knives, forming a cut pile ‘velvet’. The product then became Wilton.

Both loop pile and cut pile Wilton carpets have two or three weft shots per row of pile, as opposed to two only in the Brussels quality.

The Wilton loom became power driven by Bigelow of USA in 1849. For the next hundred years, Wilton held its position synonymous with high quality and elegance. It could be very heavy weight, very expensive and slow to produce.

Very fine carpets (i.e. with a high number of tufts per unit area) can be made by the Wilton method. The finest qualities use worsted yarns although semi-worsted and woollen-spun yarns are also utilised.

\[
\text{Brussels carpet structure}
\]
Although the percentage of Wilton carpet produced has decreased, it is still important, and the finer cut pile qualities are accepted as being a superior type of carpet with reference to performance and velvet appearance.

Wilton carpets can be made with up to five major colours, with additional ‘spot’ colours available by planting them in certain parts of the design. Designs are generally limited to reasonably small geometric shapes. The tailored appearance due to the precise placement of the tufts in loop pile and the cut/loop variations provides a quality image in addition to performance.

**Yarns used in Wilton Carpets**

Wilton carpet is constructed from:

- **Pile Yarns** – they can be spun from any of the carpet pile fibres but the usual fibre composition is 100% wool or 80% wool and 20% nylon. 2-ply and 3-ply yarns are most common. Yarns can be dyed in hank form, but because Wilton carpets are often plain or have a simple geometric pattern, the dyeing in loose stock form is advantageous for colour uniformity. High twist yarns are heat set in an autoclave or chemically set in order to achieve good twist set characteristics.

- **Chain Yarns** – these yarns need to be strong, as they are the warp of the carpet structure. Linen was used in the past for the chain yarns but due to the cost of these yarns, cotton and synthetic yarns are now used. Polyester and polyester/cotton blend are common chain yarns and rayon and polypropylene have also been used.

- **Stuffer Yarns** – the stuffers give strength and body to the carpet backing which helps to hold the pile yarn firmly in the backing structure. These warp yarns are usually of a heavier count than the chain and the weft yarn. Cotton and linen have been used in the past but jute is the common stuffer yarn fibre, with polypropylene becoming more widely used. Kraft paper yarns have also been used for stuffers.

- **Weft Yarns** – cotton and flax have been used for weft yarns but jute is the standard weft yarn fibre. Kraft paper, rayon, polypropylene and polyester are also being used.
Wilton Preparatory Processes - the processing of yarns for Wilton carpet.

**Dyeing**

Pile yarns are loose stock dyed, in yarn form either in hanks or, in package form in a pressurised dye vessel.

Some cotton chain yarns may be dyed in package form. Their use is as a selvedge indicator to ensure that all pile is in the same direction when the finished carpet is installed.

**Beaming of Backing Yarns**

The stuffer yarns and the chain yarns are fed to the loom from separate beams. It is essential that an even tension is applied to the warped yarns from the start to the finish of the beam and, in each end across the beam. Uneven tensions will cause weaving faults.

A starching process may be incorporated into the beaming stage to improve to the weaveability of the warp.

The process is then called wet beaming and involves the following processes:

- Placing the yarn on a creel, so they can run through a starching bowl
- Squeezing out excess starch solution from the yarn with nip rollers
- Brushing the layer of starched yarns to separate the individual yarns
- Winding yarn onto a beam under tension.

**Hank to Cone or Cheese Winding**

This process creates packages suitable for the pile yarn creels or for beaming.

**Winding of Weft Yarns**

The weft yarns are wound from large cones onto packages. These are small yarn packages that fit inside the weaving shuttle. The packages are usually sized or starched prior to insertion into the shuttles and the carpet may be woven with a 'wet weft'. This not only aids weft yarn flexibility but also adds bulk and adhesive properties to the carpet.
Wilton Weaving

Wilton Carpet Weaving – the weaves

Carpet weaves are developments of the simplest plain weave fabric. Warp threads (warp ends) interlace with weft or cross-threads (weft picks or shots).

On a carpet loom, an additional harness, with healds or healds, controls the stuffer and pile yarns. As previously noted, carpet structures are a development of this plain weave but instead of only one pick, two or three may be inserted into the structure before changing the warp ends i.e. form a new shed.

The principle is that when the position of the warp changes i.e. when the two layers of warp threads cross over (one layer consists of even-number ends and the other consisting of odd-numbered ends), the warp ends which were underneath now come to the surface and those which were on top come down.

This action creates a shed, through which the shuttle passes, either trailing a yarn from its internal bobbin, or from a rapier carrying weft yarn. This yarn forms the weft of the carpet. The shuttle/rapier returns from the far side of the loom, again inserting the continuous weft yarn.

After each passage of the shuttle or the rapier, the inserted weft shot is ‘beaten up’ by the reed. The number of weft shots per unit length and the carpet density and quality, depend on the take up. The amount of beat up is controlled by the force used to propel the reed towards the fell of the woven structure, and the take-up rate of the woven carpet roll and the let-off or feed off the warp beam.

Wilton Plain Wire Loom Weaving

Shedding is the lifting or lowering of warp ends in order to form sheds or openings for the weft shuttle/rapier to pass through. It is achieved by means of healds which are a series of wires with central twisted wire eyes each large enough to carry a warp end. The healds are held and controlled by a harness. The supporting wires above and below the eyes are fastened to thin metal shafts which stretch across the width of the loom.

The chain warp is divided into two halves, with each alternate end threaded through one of the two back healds which lift alternately for three picks, and drop for three picks. When one half of the chain is up, the other half is down, and vice versa.
The chains intersect with the weft and form a continuous backing fabric, similar to a simple plain weave.

The pile and the stuffer are controlled by the front heddle, with the pile passing over the pile wire, and the stuffer passing under it. For every pile end there are two chain ends, and one, two or three stuffer ends.

The chain warp is divided into two halves, with each alternate end threaded through one of the two back heddles which lift alternately for three picks, and drop for three picks. When one half of the chain is up, the other half is down, and vice versa.

The chains intersect with the weft and form a continuous backing fabric, similar to a simple plain weave.

The pile and the stuffer are controlled by the front heddle, with the pile passing over the pile wire and the stuffer passing under it. For every pile end there are two chain ends, and one, two or three stuffer ends.

The movement of each heddle is controlled by a separate cam shedding motion.

In the case of the Jacquard loom, the three harnesses control:
- half the chain
- the other half of the chain (alternate ends)
- stuffer warp.

**Jacquard Wilton**

Unlike the plain Wilton, the pile yarn is not controlled by the third (stuffer) harness but by a Jacquard mechanism.

**Picking**

Picking is the process of inserting the weft yarn. The shuttle or rapier needle which carries the weft yarn backwards and forwards across the carpet is propelled by a mechanism arm activated by another cam on the loom.

Some of the methods used to increase weaving speeds on newer looms include the use of needles similar to Axminster looms, and rapiers to insert the weft shots.

**The Weaving Sequence**

The number of wires used is normally four times the rows per inch, i.e. 7 per inch - 28 wires, 8 per inch - 32 wires and the weaving sequence for creating a 2-shot plain loop pile Wilton carpet is:
- the warp shed is formed by the chain yarns under the control of the two harnesses
- the front harness is raised
- the shuttle/rapier passes through the shed (insertion of first weft yarn) passing under the stuffer warp and at the same time the secondary shed formed by the pile yarn has the pile wire inserted
- the rear harnesses remain unchanged, and the front harness is lowered, so that the returning shuttle/rapier (insertion of second weft yarn) this time passes over the stuffer warp and over the pile warp, locking the pile yarn tightly over the pile wire
- the rear harness now changes over, and the front harness returns to raise the pile yarns and stuffer warps
- the pile wires remain in the structure for about 12 shed changes or weaving cycles. This consolidates the pile, and ensures that there is no ‘robbing’ back to the previous tufts when creating the next tufts
- beat up during the weaving cycle is via the reed and occurs between each shed change.
the rear harnesses remain unchanged, and the front harness is lowered, so that the returning shuttle/rapier (insertion of second weft yarn) this time passes over the stuffer warp and over the pile warp, locking the pile yarn tightly over the pile wire

the rear harness now changes over, and the front harness returns to raise the pile yarns and stuffer warps

the pile wires remain in the structure for about 12 shed changes or weaving cycles. This consolidates the pile, and ensures that there is no ‘robbing’ back to the previous tufts when creating the next tufts

beat up during the weaving cycle is via the reed and occurs between each shed change.

If cut pile is required, a wire incorporating a blade cuts the pile loops on its removal from the row of loops. The wires will be long enough to cover the full width of the carpet on the loom. The standard widths are 686 mm, 914 mm, 1372 mm and 3660 mm. The height of the wire controls the height of the carpet pile. Looms have interchangeable sets of pile wires of different heights.

This weaving sequence is for a 2-shot weave. Should a 3-shot weave be specified, 3 weft yarns will be inserted.

**Beat Up**
The forcing of the pick or the weft yarn in the shed hard up to the fell using the reed.

**The Jacquard Mechanism**
The Jacquard mechanism enables the creation of large pattern repeats in Wilton carpet by selecting and lifting particular colours of pile yarn to be woven over the wire, so creating tufts of that colour in that particular area.

Mounted above the loom is the Jacquard with a harness beneath it which extends downwards through the warps in front of the heddles and behind the reed.

The traditional lifting mechanism is activated by a series of punched cards. Each card has a series of punched holes as determined by the original design. The presence or absence of holes in the card determines the pattern originally painted on squared paper with each square representing one carpet tuft.

The cards are laced together, side by side, to form an endless lattice which is supported on the loom and passes around the card cylinder (actually a square section roller). Electronic control of the Jacquard mechanism is becoming increasingly widespread.
As weaving proceeds, each card in turn is brought into position against the face of the cylinder, where long needles are pressed onto the card. If a needle enters a hole in the card as the card cylinder moves towards the right, then the upright hooks, which are threaded through loops in the horizontal needles, are not moved sideways.

These hooks still contact the rising griffe and via the harness, raise the appropriate pile yarn. If there are no corresponding holes in the card, then as the card cylinder is moved to the right, the horizontal needles are displaced to the right and the upright hook misses the griffe and is not raised. The pile ends controlled by this hook and harness remain still and are not woven into the backing alongside the stuffer yarns. Up to five ‘frames’ of yarns may be used on a Wilton carpet, although because this means there is a lot of yarn in the back of the carpet, three frames is usually the largest number used.

When the shed changes and the next pile wire is about to be inserted, the card cylinder revolves to expose the next pattern card in the series. Depending upon the holes punched in the card, certain ends are raised by the harnesses to pass over the pile wire to form a pile tuft, while the others remain down and are woven into the carpet backing.

The concept of ‘planting’ small areas of highlighted colours in the five frames can extend the patterning capacity of the Wilton loom but for intricately patterned woven carpet, Axminster is the more efficient production method.

**Face to Face Wilton Looms**

This method of carpet production was developed in 1947. Two carpets are woven at the same time in the form of a sandwich construction. The structure is then slit by a knife to create two separate carpets.
The advantages of this method of production are as follows:

- the weaving rate is more than twice that of a wire loom
- mirror image patterns can be created with the paired carpets and they will have much less ‘dead’ yarn in the carpet ground or backings
- they can be produced as single shot or three shot constructions.

In this construction method, an upper and a lower shuttle is necessary to form the weft of the two backing layers. Four rapiers can be used to insert a weft, at the same time, for both carpets.

Wilton Carpet Finishing

The operations involved in finishing are:

**Inspection** - the carpet is inspected for faults before and after finishing.

**Picking** - (not to be confused with the same term used for ‘insertion of weft yarn’) refers to the correction of weaving faults by hand sewing. Both the face and the back of the carpet are inspected and faults removed/repaired as necessary. For example: missing pile of the correct colour is sewn in, short tufts may be replaced, broken backing yarns repaired as well as thick yarns removed and replaced.

**Brushing** - some fibres in the pile yarn are not long enough to reach around the U-shaped base of the pile tuft and are not locked into the carpet structure by the beat-up of the carpet. These fibres will be brushed out and removed by suction prior to the shearing process.

**Shearing** – to create a uniform tuft height in cut pile carpets. The process is usually in two stages with the carpet passing pile upwards over a sharp edged metal ‘bed.’ A cylindrical bladed roller operates at an accurately controlled height above the bed. The rollers resemble the spiral bladed cutting rollers of lawn mowers in their action.

**Back Sizing or Backcoating** – while compact heavy weight Wilton carpets usually do not require sizing or backcoating. As the density and weight of the carpet is reduced, the carpet construction is less stiff and coating the carpet backing will give it the required stiffness and tuft lock. Starch was the traditional sizing/coating compound but natural latex and acrylic compounds are its replacement. The process of ‘rubberising’ suggests that some or all of the stuffer yarns traditionally used to create the carpet rigidity, may not be a necessary part of the construction.

**Steaming** - a process used to ‘burst or add bloom’ the tuft ends of cut pile carpets. This process may also even out any minor within tolerance variations in yarn count, colour or twist level.

**Measuring** - a trumeter is used to accurately measure the length of carpet rolls. With bolder patterns the repeat length of the pattern must be tightly controlled. This is usually checked by measuring the length of a fixed number of pattern repeats.
Entry of backcoating or backsizing of narrow loom carpet

Measuring of pattern repeats on Wilton narrow loom carpet

Exit of backcoating or backsizing of narrow loom carpet
Tapestry Carpet

Machine made tapestry carpets are similar in construction to Brussels or Wilton carpets and they be either loop or cut pile. Although this method is virtually no longer used, it does have a unique method of creating multi coloured complex patterns in the pile. The carpet is woven from a printed pile warp without the use of a Jacquard mechanism.

The weaving process is quite fast and efficient and being effectively a single frame carpet, there is no dead yarn in the backing. The first stage of the carpet production is the preparation and printing of the warp and this is laborious and expensive.

To print the yarn, a sheet of pile yarn containing enough ends for the full width of the carpet is stretched around a large drum. The drum is slowly rotated and rollers immersed in troughs of the various colours required for the design are brought into contact with the yarn at the bottom of the drum.

The length of each coloured section will depend on the carpet pile height and the shot rate.

The coloured dye pastes are squeezed into the pile yarn, which is removed from the drum, steamed, rinsed and dried.

The various sections of printed yarn are then arranged in sequence on a creel so as they enter the loom, the required pattern is created.

The patterns produced by this method are not very precise due to variable colour penetration in the pile yarns, some bleeding of colours, and variable yarn shrinkage during the steaming operation. As a result, this throws the synchronisation of colours out.

Axminster Carpet Manufacture

History

Axminster is the name of a town in England where carpet manufacture was carried out between 1750 and 1850. The carpets were made on upright looms with Turkish knots and the carpets had little in common with the machine made Axminster carpets.

The Spool Axminster loom, originally called the Royal Axminster loom, was developed in New York in 1876. This loom enabled the set of an unlimited number of colours in carpet design.

In 1890, the British firm of Brintons developed the Gripper Axminster process which adopted the Jacquard mechanism in the Axminster process. While this process has limitations on the number of colours which can be used, it is a faster process because it eliminated the yarn preparation stage necessary with the spool Axminster loom (and also with tapestry and chenille). Later, the operating principles of the spool and the gripper Axminster systems were combined to create the Gripper-Spool Axminster loom.

Even though Chenille Axminster has now largely disappeared as a manufacturing method and there is no carpet stock available, it has an interesting history.

Chenille Axminster was developed in 1838 and became the first powered loom where there was no limit on the number of colours that could be used to create pattern, as in hand knotting.
While Chenille Axminster is not made in Australia or New Zealand, the carpet is produced by two successive weaving operations:

- Production of the chenille fabric from which the chenille fur is produced
- Weaving of the carpet with the chenille fur as a weft to create the pile.

**Spool Axminster Carpet**

Spool Axminster looms produce cut pile carpets with almost unlimited colour and design possibilities.

Axminster carpets in general have a high proportion of the pile yarn appearing as tufts above the carpet backing structure.

The weaving efficiency of Axminster is similar to Wilton but the spool setting operation is quite labour intensive adding extra cost.

The manufacture of Spool Axminster carpet is in two stages:

Stage 1 - is ‘setting’ the pile yarn (supplied from bobbin or cheese) in the correct sequence onto a series of spools. Controlled lengths of yarns, in the sequence needed for a row in the pattern, are reeled onto each individual spool so that the waste left when the first spool runs out can be minimised. These spool pattern chains are supported on a gantry.

Stage 2 - is weaving where the spool pattern chains are brought mechanically into their correct position so that the spools of yarn may be transferred in sequence from the chain to the weaving position.

**Yarns used in Axminster**

Axminster carpets are constructed from:

- **Pile Yarns** - these can be spun from any of the available carpet fibres or blends. They are usually woollen spun with a resulting heavier yarn count with better bulk characteristics than yarns used in Wilton carpets. Yarns are usually dyed in hank form. Some high-twist yarns can be included in designs as a highlight or feature.

- **Chain Yarns** - these yarns serve the same purpose as they do in Wilton carpets i.e. they are the warp of the carpet structure and are usually similar with cotton and cotton/polyester the major fibres used.

*Polyester/ Cotton Chain Yarn*
Stuffer Yarns – yarns that are similar to their Wilton equivalents i.e. yarns give strength and body to the carpet backing which helps to hold the pile yarn firmly in the backing structure. Jute is the most common. Kraft paper, viscose and hemp have been used in the past with polypropylene becoming more widely used due to its price and ease of use.

**Jute Stuffer Yarn**

Weft Yarns - Jute and polypropylene yarns are used as weft. These are inserted by steel needles (needle insertion method) fed directly from large cones or cheeses.

**Jute Weft Yarn**

### Preparatory Processes of Yarns for the Axminster loom

**Dyeing**

Pile yarns are usually dyed in the yarn form. Some cotton chain yarns are also dyed to be used for selvedge identification as for Wilton weaving.

**Hank to Cone or Cheese Winding**

This process creates packages suitable for the pile yarn creels or for beaming.

**Backing Yarns**

The stuffer warp yarns and chain warp yarns (often referred to as warp yarns) are fed to the loom from separate beams with similar requirements to that of Wilton beams.
Axminster Spool Setting

The first step of Spool Axminster carpet production is setting of the pile yarns following a design pattern created by hand or computer. This process produces the spools of yarn which are loaded onto the spool chain on the loom for the weaving process to create the pile.

- Setting: packages of the various coloured yarns present in the pattern are loaded onto a horizontal table creel. They are fed through separate dents of an open reed, and wound onto the spool which has metal flanges on the ends. The operators ensure the colour sequence of yarn on the spool matches the sequences on the particular line of the pattern being set.

- Example of Spool Setting - if the carpet is to have seven tuft rows per inch (7 rows per 2.54 cm) and a pattern length of 36 inches (91 cm) is to be reproduced then 252 (7x36) separate spools will need to be created and mounted on the pattern chains.

A full spool holds 11 metres of yarn and a full set of spools will produce approximately 350 metres at a carpet width of 3.66 metres with a total pile mass of 1300 g/m² and a total tuft length of 22 mm.

If a longer run of carpet is required, multiple spools of the same thread sequence will be made, before the operator/setter moves onto the next row of the pattern, and adjusts the thread up of the spool to match the coloured squares painted or printed on that row of the design paper.

If the carpet is 27 inches (69 cm) wide, the 27 inch spools will contain $27 \times 7 = 189$ pile ends for 7 pitch. A 27 inch (69 cm) carpet is often referred to as narrow loom, body or 3/4 width.

If the carpet is 36 inches (91 cm) wide, 36 inch wide spools will contain $36 \times 7 = 252$ pile ends for 7 pitch carpet. This is often referred to as 4/4 width.

A 16/4 width is commonly known as 12 foot (3.66 m) wide broadloom. This will need 4x36 inch wide spools to create the pile.
Threading: occurs when each spool is set and the ends are mechanically threaded into tube frames. One end of pile yarn is threaded through each tube. The tube frames were originally metal but many are now plastic. The tube frames incorporate springs to hold the spools into the spool chain. The length of the spool chain will vary with the pattern length. Using the previous example, a 7 pitch 36 inch pattern length will require a spool chain long enough to hold 252 spools.

Axminster Spool Weaving

As the chain moves during the weaving process, each spool is brought into position above the carpet, where it may be lowered so that the pile ends enter the courses (two chains and one stuffer end) of the foundation wraps.

The hexagonal star wheel accurately encounters the spools and positions them correctly for tuft insertion.

Chain warps and stuffer warps are controlled by heddle frames in a similar fashion to Wilton carpets. The frames are controlled by cams on the loom drive shafts and create sheds.

Wefts are inserted by one or two steel needles, long enough to traverse the carpet width. Each needle has an eye to carry the weft through the shed formed by the warp yarns.

On reaching the other side of the machine, a strong linen or cotton yarn in a selvedge shuttle intersects the weft and retains it as the needle returns to its original position.

Because of the needle insertion method, wefts are always double-shot i.e. they occur in pairs.

On every alternate shed change, the spool chain stops. The spool in the correct position is detached from the chain and lowered so that the tubes pass through the warp threads, the tuft is formed with the tuft length then cut off the spool yarn supply. The spool is then replaced in the spool chain. Note: This method of tuft insertion is referred to as the Platt Method. The Crompton Method is slightly different but has the same result.

The tuft row or pile cutting is achieved by a pair of blades. A straight blade is fixed parallel to the carpet pile and in line with the new row of tufts. A second inclined blade moves over the first blade in a guillotine like action, cutting the tuft row. As the blades cut at an angle to finally achieve a flat face, the first inserted end of the tuft looses a certain amount. This waste averages 17%, the major factor in weaving cost.
Axminster Finishing

Axminster carpets are finished in a similar way to Wilton carpets. The finishing processes are inspection, picking, shearing, brushing, back sizing/backcoating, steaming and measuring.

To provide adequate tuft bind or tuft lock, all Axminster carpets are back sized/coated. While the original sizing material was starch, the requirement for higher levels of tuft retention to be achieved led to the wide use of synthetic latex, acrylic and other plastic compounds.

Back coating improves several aspects of Axminster carpet performance:

- greater tuft retention
- improved stiffness and rigidity of the carpet structure thereby assisting the carpet installation process
- fraying of cut carpet is reduced thereby allowing more satisfactory seams other than the traditional sewn seams.
Gripper Axminster Carpet

The production of Gripper Axminster is a single stage process where yarns are supplied to the loom from frames similar to those used in Wilton carpet manufacture. The number of frames is generally commercially restricted to 8, although use of up to 16 frames is possible. Consequently, Gripper Axminster carpet is faster to produce, although it has a more restricted range of colours than Spool Axminster.

Yarns used in the gripper weaving process are similar to those for spool constructions. Preparatory processes, other than the not required spool setting, are also similar. Pile yarns are supplied to the pile creels on bobbins or cheeses.

Like Spool Axminster, Gripper Axminster constructions have a large amount of the pile appearing as pile tufts, with little dead yarn. If weft insertion is by needle, the weft is always a double-shot. Gripper Axminster carpet has a more ridgy backing construction than Spool Axminster.

Weaving of Gripper Axminster

Stuffer yarns are supplied to the loom from a beam. The two chain yarns must be supplied to the loom from separate beams due to the uneven lengths of the two chains in the structure.

The pile yarns are threaded through slots in a series of vertical carriers. For an 8-frame design, each carrier will have 8 different coloured yarns threaded through it, one above the other. There is one carrier for every pile tuft across the width of the carpet so that every time a gripper forms a pile tuft, it can select from a choice of 8 colours.

A Jacquard mechanism using punch cards, needles and hooks similar to that described in Wilton carpets, creates the pattern by raising each individual carrier to the height necessary to present the required coloured pile yarn to the gripper.

Some looms now have horizontal carriers reducing the arc or gripper movement allowing for faster weaving. Electronic Jacquards are becoming more common, allowing for almost limitless length repeats.
The gripper is the mechanism used to select and insert each pile tuft individually. Every row of tufts across the width of the carpet (usually 7 per inch or 7 pitch but 4,5,6,8 and 9 per inch are available) has a gripper. The gripper is steel and is less than 2 mm thick.

A selector is fixed to a shaft and can move around the pivot. This enables the jaws to open when presented to the yarns in the carriers. The guide locates into the top jaw and this is where control of the jaw operation takes place.

The grippers grasp the pile yarn, withdraw the required length of yarn to form a tuft from the carrier, and a knife assembly consisting of a comb and a blade moves down to cut the yarn.

The grippers then rotate forward and down with the cut length of yarn and lay the free ends of the yarn against the fell of the woven structure.

On some looms, the grippers hold the yarn and the yarn carrier draws off the set length of yarn. The needle inserts a double weft shot that is beaten-up by a special curved open reed which can pass between the grippers.

The gripper jaws open, and as they begin to move upwards, their lower jaws comb the back half of the tuft to vertical. A rake then consolidates the pile upright and two double shots are inserted. While this remains the general principle of Gripper Axminster construction, modifications including reduction of the arc travelled by the grippers have significantly improved production speeds.

**Gripper-Spool Axminster Carpet**

The production of Gripper-Spool Axminster carpet combines the advantages of both spool and gripper constructions. The carpet can have as many colours as the spool construction but it has a construction similar to the gripper which in turn, is stronger than the spool. An advantage of the hybrid process is that waste of pile yarns due to uneven cutting is eliminated. Weaving speeds are as high as the gripper which in turn, is faster than spool. However, the setting of spools is still necessary.
Weaving and Finishing of Gripper-Spool Axminster

- Weaving: the pile yarn is set onto spools which are carried by a heavy duty chain above the loom, similar to the Spool Axminster construction. However, the difference is that spools are not detached from the chains to insert the tufts as in spool weaving.

- The spools are moved into position and frequently clamped to locating blocks. Grippers then move into position and withdraw the required yarn length. A knife and comb cut the tufts. Tuft insertion into the woven structure is the same as for Gripper.

- In this construction method, the Gripper-Spool tube frame is different to the Spool frame. The pile yarns are threaded into a series of keyhole shaped slots cut into the tube frames. There are vertical metal strips attached at right angles to the frame face between each slot to form a comb.

- A small tab attached to the strips at the front of the frame ensures the yarns cannot accidentally lift out of the slots.

- Finishing: Gripper-Spool finishing processes are as used for the other methods of producing Axminster carpets.

Weaving of Chenille

- This is the process of weaving the chenille fur into carpet on a ‘weft setting loom’. The fur becomes the weft of the structure and is laid across the structure by a carrier or travelling arm.

- Special cotton warp threads called catcher threads pass between the pile tufts and interlace with the top shots of weft in the backing structure which is being woven at the same time. This binds the fur securely into the fabric structure.

- The typical Chenille Axminster backing is similar to a two shot Wilton backing construction with additional catcher threads.

- The cotton float warp is used to raise the rows of tuft in the structure. The weaving process is very slow. After it is inserted, each row of fur must be straightened and positioned by at least two operators per loom, using hand combs.
Carpet Tufting

Summary

The process of manufacturing tufted carpet involves:

- inserting tufts of pile yarn into a pre-formed backing cloth (the primary backing) from the backside of this cloth
- tuft insertion is via needles, similar to sewing machine needles
- the resulting structure is back coated with a synthetic latex compound and generally, a ‘secondary backing’ either woven jute, non-woven polyester or woven polypropylene material is applied
- for carpet ‘directly stuck to the floor’ applications, no secondary backing is applied
- carpet with an integral foam underlay is created by application of latex foam after an initial precoat to lock the tufts
- drying, curing and other finishing processes follow e.g. brushing & shearing
- the carpet is then inspected, graded, mended if required (on-line or off-line) and rolled for storage and distribution.

History

- The earliest form of tufting was more than likely the creation of rugs in Europe and achieved by hooking strips of cloth or thick yarns through a coarsely woven cloth.
- A similar technique was applied from around 1895 by Catherine Evans of Dalton, Georgia USA, to create hand crafted bedspreads. The pattern was drawn on the backing cloth and a needle was used to insert the yarns into the backing. The pile material was trimmed with scissors, washed and hung in the breeze to burst the cotton tufts. The Catherine Evans product range expanded over time to include bedspreads, bath mats, scatter rugs and cushion covers. As a result, a cottage industry emerged to produce those items, with many people working as hand-tufters.
- In 1930, a minimum wage was created for hand-tufters and this led to pressure to mechanise the process of tufting to reduce the consequent increase in labour costs.
- Domestic sewing machines were modified to handle heavy yarns and to incorporate a looper and cutter to create the cut pile tufts. Versions of these early machines are still used to overtuft special patterns on machine-made products. They often have multiple needles and may be used as 'pass machines' whereby a large area of backing material is tufted by making multiple parallel passes under the tufting needles.
- In the 1940s, the number of needles in the machines was increased and the first twelve feet wide (3.66m) broadloom tufting machine intended to produce carpets was manufactured. The first rugs and carpets produced on tufting machines had cotton pile.
- Dalton has remained both the centre of the United States tufted carpet production and the major world centre for producing carpet tufting machinery and ancillary equipment, although some tufting machinery is produced in the United Kingdom.
- Australian companies became involved with the production of tufted carpets in 1958, initially making narrow width carpets for motor cars.
The Tufting Machine and its Operation

The schematic shows the essential parts and indicates the sequence of mechanical actions of a tufting machine.

Cones of 10 inch/25cm diameter with approximately 8 lb/3.6kg of pile yarn are usually mounted in a magazine type creel (A) with fixed metal cone supports.

Yarn is taken over-end from the large cones and enters the ends of the guide tubes, about 18 inches/46cm away, through which the individual yarn ends are passed overhead (B) to prevent entanglement.

Initial threading is done by means of compressed air and the ¼ inch/6mm diameter, are numbered to relate the position in creel to the corresponding needle position. When it emerges from the tubes (tube holder bar, D), the sheet of yarn is led into the nip of the emery-covered feed rollers (C). These rollers are positively driven at a speed determined by the tension and height of pile required.

The yarn then passes through a compensating device, where the angle formed between a fixed bar (E) and a second guide bar (F) attached to the needle bar (G) enables fine adjustments in tension to be made, i.e. to slacken or tighten the yarns as required during then needling action. From the second guide bar (F), each pile yarn is presented to its respective tufting needle (H).

The row of vertical needles arranged transversely across the machine is given a vertical reciprocation motion through the open-ended slots of a reed plate (I), actuated by an eccentric shaft (J). This causes the needles to pierce the backing fabric which is drawn from the cloth roller (R) by the spiked metal intake roller (K). The latter roller is driven by the similarly constructed spiked take-off roller (L) which draws the cloth through the machine.

On insertion of the needle through the backing fabric, a looper (M) is actuated by the looping shaft (N) attached to the eccentric shaft (J), and moves forward to pass between the yarn and the needle. A loop is formed on the looper as the needle returns, and is passed along the neck of the looper as the cloth moves forward. A presser bar (P) prevents the cloth from rising as the needle is withdrawn. When a third loop is formed on the looper, the first one makes contact with a spring steel blade (O) which works in conjunction with looper (a looper is more commonly known as a hook in a cut pile tufter) and cuts the loop with a scissors-like action (see following diagram – Pile Forming Mechanism for Cut Pile).
A loop pile carpet is made by a similar action but the looper has no barb and its direction is reversed, so that as the looper moves back, the loops slip off giving a loop pile structure (see following diagram – Pile Forming Mechanism for Loop Pile).

On leaving the machine, the carpet is passed over an inspection stand and any gaps resulting from end breakages are repaired by a single needle loop gun or marked for mending off-line.

The Tufting Process

Modern tufting machines produce carpet in excess of the traditional 12 feet (3.66m) in width so that after shrinkage from the backcoating process, the carpet can be trimmed to produce a final width of 3.66 metres. Currently, 4 metre and 5 metre wide tufting machines are available.

A wide variety of needle gauges, pile heights and pile styles are created by modifying the tufting process.

Elements of the Tufting Process

Needles are fitted into the needle bar which is driven by the eccentric shaft in a reciprocating motion. The needles extend across the width of the tufter, the number depending on the gauge and the machine width.

Supply Creel:

The supply creel stands behind the tufter and holds the cones of pile yarn. The number of cone pegs required will depend on the number of needles across the tufter which in turn depends on the gauge of the machine.

The cones are mounted on cone holders, spaced vertically on a series of frames which make up a creel. All creel tubes are numbered at the creel and on the tufter. This allows recognition of ‘lost’ ends i.e. yarn ends that have broken or run-out.
For example, a 1/8 gauge machine tufting a width of 12.5 feet (3.81 m) will require 1200 cones of yarn to supply the needles. The figure of 1200 is normally doubled because each yarn guide tube needs to access two cones (one of which is joined nose-to-tail or top-to-bottom to the other) to ensure that the yarn feed continues when the first cone runs out. The empty cone is then replaced with a full cone, the start of which will be joined to the tail of the one being used. In this way, the yarn supply to the machine is continuous.

It is important that the distance the yarn has to travel from the cones to the needles is as uniform and as short as possible. This reduces problems associated with varying degrees of elongation between yarns and across the width of the carpet, caused by friction in the tube and by the natural stretch of the yarn when under tension. Tension differences can result in texture and/or pile height variations.

**Yarn Guide Tube**

The yarn guide tube constructed of tough, hard plastic takes the pile yarn from the cones to the feed rollers of the tufter. To minimise friction on the yarn, the tubes are positioned to ensure there are no sharp corners for the yarn to negotiate.

Each tube has a ceramic guide inserted at the feed end to prevent premature damage of the tubes by the yarn. While these ceramic inserts are extremely hard, synthetic yarns in particular moving at considerable speed and under tension, may quickly wear grooves in them leading to yarn surface fuzzing (fibrillation) and breakage as the groove becomes deeper.

The correct positioning of the supply cones in relation to the guide is critical. If it is not positioned reasonably close to the central axis of the feeding cone, the tension on the yarn as it unwinds over the top shoulder of the cone will fluctuate during each revolution of unwinding, causing tension related faults in the carpet pile.

**Beams**

They are an alternative method of supplying yarns to tufters. Beams occupy less space than a creel but can only be used when a uniform level pile texture where the rate of yarn feed required for each needle is the same, is required e.g. fine gauge plain, non-patterned level loop. Beams are unsuitable for patterned constructions where yarn consumption at all needles is not identical. In addition, the tufter must be shut down to change beams.

Pile yarn beams are created in a similar fashion to those used for plain Wilton carpets where cones of pile yarn are mounted on a creel and a series of beams are produced. The beams are then positioned behind the tufter and yarn ends are joined to those of the previous beam when beam change becomes necessary.

**Advantages of using beams include:**

- more even tension in the pile yarns as the beam creels do not generally use guide tubes
- the creeling of cones of yarn (prior to beaming) is situated away from the tufting area
higher tufting machine efficiency is available within batch runtime as there is no ‘cone change over’ attention needed
down time due to rewinding or bit-winding can be tolerated during the beaming process but it is not economical during the tufting process due to the loss of production that will occur
higher overall running efficiency on level pile carpets.

Yarn Joining
Joining of two yarn ends is achieved by either air splicing, glueing or knotting or heat welding on synthetic yarns. As the ‘glueing’ option attracts soiling materials, glued joins must be cut or mended out after tufting. Single or double knots with long tails should also be removed as part of any quality assurance program. There are specialised devices available for quick joining of whole beams with heat welding.

Air Splicing
The use of splicing is preferred. The air splicer is driven by compressed air and the two ends to be spliced are placed in the cutting trough of the splicer where the ends are trimmed, opened and entangled by air. The splice is formed by combining the fibres of each end and this provides a join with minimum bulk, maximum strength and no foreign material.

Feed Rollers
The feed rollers draw the yarn off the cone and through the tubes and supply it to the tufting needles at a constant rate. The rollers are usually covered with fine emery paper to ensure that there is a strong, consistent grip of the yarns. The last roller is usually either rubber covered or textured to ensure the yarn releases cleanly from the roller. More than two rollers may be used to achieve the positive feed. In a ‘plain’ tufter i.e. one which provides a level pile carpet either loop pile or cut pile, the feed rollers supply all the pile yarns at an identical rate.

If different pile yarns are controlled by different sets of feed rollers which operate at different or varying speeds, then a variety of pattern effects can be created in the carpet pile. This patterning principle is based on the fact that during the needle insertion and the loop forming stage of tufting, the loop being formed can be ‘robbed’ back from the previously formed loop. The amount of yarn robbed back will depend on the tension of the pile yarn supplied to the needle, which depends in turn, upon the length of yarn supplied and therefore on the feed roller speed.

Guides
The yarn travels between at least two guides on its path from the feed rollers to the needle. These guides may be simple holes in metal bars or more sophisticated hard wearing ceramic guides. One of the guides that each yarn passes through may incorporate a stop motion which will stop the tufter in the event of any yarn break.

The jerker bar is attached to the needle bar and so moves up and down during insertion and withdrawal of the needles. The fixed yarn guide is adjustable in height and this is used to alter the length and angle of the yarn.
The jerker bar takes up slack yarn supplied by the feed rollers during the upstroke of the needles, and is adjusted to supply the correct length of pile yarn, which will produce a level pile with a tight back stitch.

When an end break occurs, the yarn supply to the needle is interrupted resulting in missing pile in the carpet. To replace the broken end, the tufter needs to be stopped so the needle can be rethreaded. Additional yarn will need to be delivered from the cone and the operator uses a compressed air jet to feed the yarn through the tube. The yarn is then threaded through the feed rollers and yarn guides and through the needle eye. When an end break does occur, a missing tuft or missing tufts can be replaced at the back of the tufter on a frame connected to the finishing/mending area.

**Eccentric Shaft**

The eccentric shaft transmits the rotary action of this shaft into the vertical reciprocating action of the needle bar. The drivers for the needle bar, loopers and knives must be timed to ensure efficient operation.

**Needle Bar**

The needle bar holds the needles which form the pile tufts. When setting up the machine, great care must be taken to ensure that the height of all the needles above the reed plate is identical. During the tufting operation, needles can break or become blunt and must be replaced.

To increase needle change-over speed and simplify the setting or tuning of the needles, modern tufters use modular sections of needles with clamps to the needle bar. Any replaced module of needles can then be inspected, away from the tufter, in a workshop environment and either be repaired or discarded.

The needles may be positioned in the needle bar in such a way that they can be used to create many small geometric patterns. The needle bar (straight or staggered), can be moved sideways to create zig zag patterns of pile tufts rather than straight lines. Tufters with such capabilities are referred to as sliding needle bar machines.

A variation which creates wider patterning opportunities is the use of double sliding needle bars. Two independently controlled needle bars are threaded with alternate ends from the creel, or two different beams.

**Reed Plate**

The reed plate supports the primary backing fabric as it passes under the needles. The needles pass down through the primary backing fabric and through slots on the reed plate. The height of the reed plate above the machine bed is adjustable, and controls pile height in conjunction with the pile yarn supply rate. The reed plate consists of open ended slots with reeds between them. The deeper the reed fingers, the better they control the stitches, ensuring that adjacent rows of stitches are kept apart and ensuring that loops do not twist into the adjacent row of tufts. The reed plate is made up of sections and it is vital that each section is set at the same height. Looper settings and needle heights are also critical.

As the lowest position of needles, referred to as Bottom Dead Centre (BDC), needs to be constant to allow correct interaction with the loopers, there is a limit to how high the reed plate can be raised to increase the pile height produced. This limit is determined by the fixed stroke of the needle bar and the length of the needles.
If the reed plate is raised too far then the needles will not be able to clear the primary backing fabric. A lower pile height limit also exists.

The lower limit on cut pile is determined by the depth of the reed plate wires and the profile of the hook.

On loop pile the lower limit is determined by the properties of the yarn, and a combination of jerker setting, reed plate wire depth and the ability of the primary backing to control low loop heights.

Loose back stitch will occur when the reed plates are set to low relative to the amount of yarn feed.

These limitations of maximum and minimum pile heights can be overcome by fitting an adjustable needle stroke. The Bottom Dead Centre (BDC) position remains constant but the Top Dead Centre (TDC) height of the needles is adjustable.

**Spiked Intake and Take Off Rollers**

Are controlled by the same drive and control the rate of passage of the primary backing fabric through the tufter. The needles reciprocate at a constant rate and the stitch rate inserted in the primary backing fabric is adjusted by altering the speed of these two rollers. The primary backing fabric must be kept taut between the two rollers, to ensure even spacing. An additional spiked roller or pair of spiked rollers may be incorporated close to the tufting needles and used to move the primary backing fabric sideways as it passes under the needle. This is called the jute shift mechanism (named when primary backing fabrics were available only as woven jute) and is a common method used to create a wave or zig zag pattern during the insertion of tufts into the primary backing fabric.

**Presser Bar**

The presser foot bar ensures that the primary backing fabric does not lift up as the needles are withdrawn. On cut pile tufters, the pressure bar may not be necessary because the loops trapped on the looper, prior to cutting, act to tightly hold the primary backing fabric down.

**Loopers**

Loopers are moved by the looper shaft which moves the loopers forwards and backwards in relation to the needle position.

Each needle operates in conjunction with a looper. When the needle reaches its lowest position, the looper comes alongside the needle and retains the pile yarn as the needle rises up out of the primary backing fabric. The needle has a designed cut-away to allow space for the looper and the yarn.

**Knife**

In order to create cut pile carpet on the tufter, a knife needs to act in conjunction with the lower edge of the hook to shear the pile yarn. The knives need to be sharpened periodically and after being removed from the tufter, the knives are ground to give a flat end with a sharp edge.
Primary Backing Fabric Roll
The roll of primary backing fabric is mounted on a shaft in front of the tufter. The backing fabric is unrolled by the action of the spiked roller and it is important that the tension on the backing fabric is constant throughout the length of the roll. A braking mechanism ensures that there is no over-run on the roll when the tufter is stopped.

Gantry/Inspection/Perch
A gantry or inspection frame is positioned at the back of the tufter. This area is brightly lit to aid in the detection of faults by the inspectors, who view the carpet passing up the rear of the tufter, over their head on the gantry and down the other side. The carpet is then carried by a series of rollers to be folded into trucks or rolled onto cardboard cylinders. The gantry incorporates an accumulator section. This allows the inspector/mender to operate this section of the machine independent of the actual tufting section which can maintain the tufting rate while inspection/mending takes place.

Faults and Corrective Measures
Some faults which may be encountered at this stage and the corrective measures that can be taken are:

<table>
<thead>
<tr>
<th>Fault</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>missing tufts, usually caused by pile yarn end break</td>
<td>replace missing tufts with mending gun</td>
</tr>
<tr>
<td>high loops in pile carpet</td>
<td>remove and replace with mending gun</td>
</tr>
<tr>
<td>latex joins, yarn slubs, stained tufts</td>
<td>remove and replace with mending gun</td>
</tr>
<tr>
<td>high tufts or uncut tufts in cut-pile carpet</td>
<td>clip tufts with shears</td>
</tr>
</tbody>
</table>

Replacement tufts are sewn in with an air operated mending gun. The mender inserts the tufts from the rear of the primary backing fabric. The inspector stands on the pile side and controls the pile height of the tufts being inserted by means of a remote switch.
Formation of the Pile

**Loop Pile**

In loop pile, the needle with pile yarn goes down through the primary backing fabric and as it moves up from its lowest position, the yarn is caught by a looper, below the fabric. When the needle moves upwards out of the fabric, the looper holds the yarn to form a loop.

As the needle starts to come down for the second time, the looper moves backwards and the yarn loop is released. At the same time, the fabric is moving continuously forward and this helps to clear the loop from the looper. The needle continues down to its lowest position, a new loop is made and the cycle starts again.

**Cut Pile**

The hook faces against the direction of the primary backing fabric movement. The needle, threaded with pile yarn, penetrates the primary backing fabric then moves down the maximum amount. The hook begins to move forward to engage the loop and the knife also moves down the hook shank.

The hook holds the yarn loop as the needle withdraws. The knife action is created by the ground end of the knife operating in a shearing action with the sharpened underside of the hook. The needle then returns to the Top Dead Centre position and starts the next tuft insertion. The hook moves back out of the way of the needle and the knife begins to retract.

The knives are high tensile steel or harder alloy steel and when new are approximately 150 mm long. They have a similar width and thickness to a hacksaw blade (without the teeth). As the cutting of the yarn takes place on the side or edge of the hook, one leg of each pair of cut pile tufts formed from each loop is slightly longer than the other, this is commonly referred to as ‘J cutting’. In a plush pile, failure to minimise the degree of J cutting effect may create an unwanted ‘rib’ appearance. Shearing of the finished carpet roll will not always remove this effect.
Tufted Carpet Construction and Machine Settings

The major factors influencing carpet quality and style are:

**Pile Yarns**

Some of the yarn variables are:

**Fibre Content**

As well as the major types of fibres, there are also many variations in fibre properties within each type. For instance, wool fibres vary from each other with regard to diameter, length, colour, extractable matter, lustre, medullation, strength and crimp.

Synthetic yarns may vary in colour, staple length, diameter (commonly referred to in terms of denier, but more correctly in decitex), texturing, lustre, dye affinity, special chemical additives and surface finishes.

**Fibre Blends**

The fibres can be blended to create yarns and ultimately carpets which combine the best qualities of each fibre in the blend. It is often stated that the main purpose of a fibre blend is to reduce fibre and yarn costs. However, enhanced carpet performance, increased levels of twist set in cut pile structures and the ability to create different yarn effects to add more interest in the carpet pile are more often than not, the reasons for blending different fibres together. For example: multi coloured effects can be created by blending different colours together known as tweed or heather mix depending on the form of effect added to the blend.

Wool Berber blends are created by mixing together various coloured wools. Some of the wool types may be naturally coloured but most of the colours are now dyed prior to blending to ensure adequate colour, shampoo and wet fastness properties can be achieved. The use of knops, slubs and neps which are small bundles or balls of entangled fibres, varies the carded-in effect within the yarn and adds colour highlight areas to the carpet pile.

Air entangling different colour filaments together is used to create a berber-like effect in nylon yarns.

**Spinning Systems**

Continuous filament yarns have different manufacturing and performance characteristics to spun staple yarns. The choice of staple spinning systems (usually woollen system or semi worsted system) effects the characteristics of the spun yarn, particularly yarn twist set ability, hairiness, bulk, strength and lustre level of the yarn.
Yarn Count
This is the measure of the linear density or the weight per unit length of the yarn. The coarseness or fineness of yarn may be expressed as a count or yarn number, in terms of either “length per unit mass” or “mass per unit length”. A number of different yarn count systems are used globally so it is important to know the count and system when specifying, purchasing and manufacturing yarns and carpets.

Some examples are:
- Denier: mass in grams of 9,000 metres of yarn
- Tex: mass in grams of 1,000 metres of yarn
- Metric: number of kilometres per 1000 grams
- Dewsbury: number of yards per ounce

While the Tex system as the internationally recognised system is preferred in Australia, denier is still commonly quoted for synthetic yarns.

Twist Level
The amount of yarn twist affects yarn and carpet performance, and appearance. Higher twist produces leaner, harder, higher lustre, more resilient yarn. If the yarn is to be used in a cut pile carpet, the twist must be set, so that it will resist the tendency to unravel.

Heat setting is used for thermoplastic synthetic fibres, e.g. nylon, while chemical (bisulphite), steam, hot water or setting during hank dyeing is used for wool.

Ply Twisting
Two, three or four singles yarns may be twisted together to create a multi-ply yarn. The ply twist level may be varied to create different effects. Combining different coloured singles yarns creates a stipple effect.

While a multi-ply yarn is more expensive to produce than a single yarn of equivalent count, advantages include stronger and more resilient yarn, better twist set and enhanced performance in carpet form.

Texture Modification
This means altering the structure of fibre and yarn chemically or mechanically. The knit-de-knit process (knit yarn, set and de-knit from the sock) imparts an accentuated kink when the yarn is in the carpet. Synthetic yarns can be crimped by a variety of processes, entanglement gives false bulk to a yarn and wool yarns can be felted. Stuffer Box attachments are commonly used on heat set lines to add texture to yarns.
**Tufting Gauge**

The gauge is the distance between the needles across the width of a tufting machine and unlike the stitch length, it cannot be altered by a simple machine adjustment. Changing the gauge requires changing the needle bar on which the needles are held and the associated gauge parts.

<table>
<thead>
<tr>
<th>Gauge in Inches(“)</th>
<th>Number of Needles per Inch (25.4mm)</th>
<th>Number of Needles per 10cm (100mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/20</td>
<td>20.0</td>
<td>78.0</td>
</tr>
<tr>
<td>1/16</td>
<td>16.0</td>
<td>63.0</td>
</tr>
<tr>
<td>5/64</td>
<td>12.8</td>
<td>50.0</td>
</tr>
<tr>
<td>1/12</td>
<td>12.0</td>
<td>47.2</td>
</tr>
<tr>
<td>1/10</td>
<td>10.0</td>
<td>39.4</td>
</tr>
<tr>
<td>1/8</td>
<td>8.0</td>
<td>31.5</td>
</tr>
<tr>
<td>9/64</td>
<td>7.1</td>
<td>28.0</td>
</tr>
<tr>
<td>5/32</td>
<td>6.4</td>
<td>25.0</td>
</tr>
<tr>
<td>3/16</td>
<td>5.3</td>
<td>21.0</td>
</tr>
<tr>
<td>1/4</td>
<td>4.0</td>
<td>15.7</td>
</tr>
<tr>
<td>5/16</td>
<td>3.2</td>
<td>12.6</td>
</tr>
<tr>
<td>3/8</td>
<td>2.7</td>
<td>10.5</td>
</tr>
<tr>
<td>15/32</td>
<td>2.1</td>
<td>8.4</td>
</tr>
<tr>
<td>1/2</td>
<td>2.0</td>
<td>7.9</td>
</tr>
<tr>
<td>5/8</td>
<td>1.6</td>
<td>6.3</td>
</tr>
</tbody>
</table>

**Stitch Rate**

This is the number of stitches per unit length inserted along the length of the carpet. The practical lower limit to the stitch rate is when the backing begins to ‘grin’ through the tufts and the primary backing fabric becomes visible. The upper limit is the yarn count (thickness) and tufting gauge, both of which combine with the stitch rate to create a maximum stitch density.

The stitch rate, expressed as the number of tufts per 10 cm, is controlled by the speed of the primary backing fabric and the speed of the needle insertion.
Pile Height

This is the height of the pile above the primary backing fabric when the pile is upright. It is dependent on the distance of the reed plate (which supports the primary backing fabric under the needles) above the loopers. The other determinant of pile height, as previously discussed, is the yarn feed rate.

If the reed plate height is adjusted then the yarn feed rate will also need to be adjusted to avoid:

- needle or yarn breakage
- loose back stitches

Pile Thickness

Difference in the thickness of the carpet before and after the pile above the substrate (the primary backing fabric) has been shorn away. Measured under a standard pressure of 2kPa, the measurement takes into account pile lay. At the pressure of 2kPa, this is just sufficient to buckle protruding fibres without compressing the pile.

Pile thickness will be significantly less than the pile height.

Finishes

The finishing process of tufting has some features that are common to woven carpets but also some major differences. Inspection and mending of tufted carpet is carried out on a perch which is a vertical frame behind the tufting operator. Inspection and mending are carried out together on the back of the perch and the carpet is folded into a flat trolley or jumbo rolls before steaming and backcoating.

The carpet is tied to a feed cloth and enters a J box for the finishing process. The J box allows a continuous and uninterrupted feed to occur. As the carpet progresses it is thoroughly steamed. This allows it to accept the pre-coat latex/latex backing compound more readily, bursts and evens the pile and initially makes it more flexible.

Often a thin rich latex solution (pre-coat) is applied to penetrate the backstitch and lock in individual fibres.
A thick coating of latex is then applied to the back then a secondary backing fabric of hessian, woven polypropylene or non-woven polyester is applied to the latex and primary backing fabric combination, to complete the assembly, and squeezed together to ensure good contact. The assembly then spends time advancing through an oven section to cure the latex compound and to give the maximum tuft bind and secondary backing fabric adhesion.

Prior to entering the oven and while the latex is still wet, the edges of the carpet are caught by tenter hooks. These hooks ensure that the carpet is held at a stable and uniform width while in the oven.

When a manufacturer offers foam backed carpet, the foam is applied in a similar fashion to secondary backing fabric. However, the carpet enters the finishing machine pile face down and the foam is applied to the back. The foam provides structure stability, tuft bind and solid carpet back all in one step. Foamed backed carpet has the benefit of not requiring underlay but is very heavy to handle.

After curing and cooling the carpet may be sheared to create a smooth surface finish in a velvet or plush pile, cutting of some loops to achieve a cut/loop texture or defuzzing of either cut or loop pile structures. The carpet is then rolled and accurately measured.

Tufted Carpet Styles

General

Tufted carpets were originally produced in loop pile and in coarse or wider gauge qualities. Despite the efficient production methods and good wear performance of the tufted carpets, they had little consumer appeal compared to traditional Axminster and Wilton carpets, which could display various degrees of patterning, and which were available in cut pile styles.

The earliest commercial products were limited to loop pile rayon which had poor performance and appearance retention characteristics.

In the 1960s major moves were made in simple patterning devices and the introduction of more suitable fibres and yarns. Possibly the most attractive feature of tufting was and is the production efficiency and speed. This is reflected in the price and this soon made tufting the dominant carpet manufacturing method globally.

With fast track developments in technology, tufted carpet manufacturers are able to produce patterned carpet almost indistinguishable from woven Axminster and Wilton carpets.
Carpet Styles - Loop Pile

**Level Loop**
This is the simplest style of tufted carpet to produce. The pile comes from the backing to its full height, forms a loop and returns to the backing. The pile loops are all of equal height and uncut, making a smooth and level surface. Carpets of this style are used in dense constructions suitable for residential and contract installations. Heavier count yarns with lower twist are used to produce ‘berber/heathermix/tweed’ loop pile carpets.

The almost universal use of a secondary backing fabric (or foam backing) on tufted carpets has remedied early problems of ‘snagging’ of loop pile carpets due to poor tuft retention characteristics.

**Multi-Level Loop**
This is also referred to as high-low loop or sculptured loop. As these names imply, this carpet is made up of different pile heights, two or three different heights being the most common. The difference in height creates a surface that can be described as sculptured, with the pattern appearing to have been carved from the carpet.

Patterns can be large and flowing or small and regular. Carpets must be of sufficiently dense construction to prevent the pattern ‘walking out’ in high traffic areas as in some of the pattern areas only alternate ends appear as the pile, the others being ‘buried’.

**Tip Shear**
This effect is created by tufting a two-pile height loop pile carpet and shearing the higher loops back to the same level as the lower loops. This adds another dimension to the multi-level pile pattern effect. The general effect is to create a darker coloured area due to the fact that the cut pile end reflects less light than the side of the pile which are visible in the loop or uncut pile. As the pile yarn is not generally twist set for loop pile production there is a danger that the tip-sheared areas being cut pile may rapidly change appearance from the effects of trafficking and maintenance.

**Random Shear**
Here the multi level loop carpet is sheared enough to convert the highest loops to cut pile. The cut pile remains higher than the levels of the other loops.

Using shearing to create a cut pile carpet from a loop pile carpet leads to the wastage of a significant amount of pile yarn. The effect is rarely perfect as some lower tufts in the planned sheared-pile area may be too low to be completely cut in the shearing process. Unshorn yarn loops will then appear as bright spots in the darker cut pile. The development of cut/loop pile tufting machines has reduced the use of the random shear technique.
**Carpet Styles - Cut Pile**

There are different classifications of cut pile carpets, and these refer mainly to the twist level of the pile yarn and description of the pile length.

**Velvet**
Velvet yarn has very little twist and may not be heat set. The pile tufts are 'burst' similar to a velour but velvet has a longer pile length. Both velour and velvet have a short pile length.

**Plush**
Plush yarn has a little more twist than a velvet pile carpet, and is usually set to retain this twist (water, steam, dye or chemical setting are used to set wool yarns).

**Saxony**
Two or more singles are twisted together at a medium twist level, twist set, and tufted into a dense construction. The surface texture usually exhibits 'pin point' tuft definition with medium pile length.

**Hard Twist**
The hard twist style is also known as Frieze (pronounced 'freezay') or curled pile. The yarn is tightly twisted and in a snarled configuration. The carpet displays both sides and ends of yarns, and the random lay of the pile makes it impossible for whole areas of pile to lie over in opposite directions, and so disguises flattening in traffic areas. Also, the shadows created by the tightly defined tufts further help to disguise short footsteps. The high yarn twists reduces 'shedding' of short fibres, which occurs in cut pile carpet made from staple yarns.
Style Comparison

Shag
The pile tufts are very long and create a low density construction, because the spacing of the tufts is more open than other carpet constructions. The popularity of shags has declined due to the radical change of appearance experienced in traffic areas. Traditional shags are high maintenance requiring frequent vacuuming and raking with a special carpet rake to retain a satisfactory appearance. Semi-Shag or splush is similar to a shag but has a shorter pile length.

In recent times, the Shag style has been redeveloped using heavier yarn counts and in some instances felted or highly twist set yarns. In addition, the pile density has increased to produce a high performance product for residential wall to wall carpet and rugs.

Cut Pile Style Descriptions Table

<table>
<thead>
<tr>
<th>Cut Pile Style Description</th>
<th>Pile Length Description</th>
<th>Pile Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shag</td>
<td>Long</td>
<td>≥20mm</td>
</tr>
<tr>
<td>Semi Shag (Splush)</td>
<td>Medium to Long</td>
<td>≤20mm</td>
</tr>
<tr>
<td>Plush</td>
<td>Medium</td>
<td>≤15mm</td>
</tr>
<tr>
<td>Saxony</td>
<td>Medium</td>
<td>≤15mm</td>
</tr>
<tr>
<td>Velour</td>
<td>Short to Medium</td>
<td>≤12mm</td>
</tr>
<tr>
<td>Velvet</td>
<td>Short</td>
<td>≤10mm</td>
</tr>
</tbody>
</table>
Cut and Loop
Also known as carved or sculptured pile, it is basically a cut pile carpet with areas of loop pile sculptured areas designed into it. This carpet is used mainly in residential applications. Fine or small areas of loop pile design are avoided, as the adjacent cut pile ends will spread out during use and conceal the lower loops in the sculptured area, destroying the subtle pattern.

Cut and Cut
A recent development of the cut/loop process is cut/cut or cut and cut where the low pile is also cut pile rather than loop pile. This effect more closely reproduces the ‘hand carved’ effect of hand-made sculptured carpets.

Level-Cut Loop
The level-cut loop machine creates cut pile and loop pile tufts of the same height. The pattern repeat is effectively unlimited as every hook in the machine has individual control which can precisely determine if the tuft is to be cut or loop. The pattern can be enhanced further with the addition of a shifting needle bar and full repeat scroll.

Yarn Effect
Even within the mechanical options for pile creation, various effects can be gained from presenting the tufting machine with different yarns. Different yarns shown in the following list alter the texture of the carpet.

<table>
<thead>
<tr>
<th>Frieze</th>
<th>Mock Spun</th>
<th>Heather</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felted</td>
<td>BCF</td>
<td>Stipple</td>
</tr>
<tr>
<td>Saxony</td>
<td>Tweed</td>
<td>Knit de Knit</td>
</tr>
<tr>
<td>Heat Set</td>
<td>Woollen Spun</td>
<td>Pixilated</td>
</tr>
<tr>
<td>Non Heat Set</td>
<td>Semi Worsted Spun</td>
<td></td>
</tr>
<tr>
<td>Air entangled</td>
<td>Berber</td>
<td></td>
</tr>
<tr>
<td>Cabled</td>
<td>Space Dyed</td>
<td></td>
</tr>
</tbody>
</table>
Pile Control Mechanisms

Patternning Principles

In order to create the multi-pile height styles, a variety of mechanisms have been developed to control the rate of feed pile yarn to the tufting needle. When yarn is supplied at a ‘normal’ rate, high loops will be formed in the case of loop pile carpet or cut pile will be produced on a cut pile tufting machine. When the yarn feed is reduced, the tuft being created ‘robs’ back a considerable amount of yarn from the previously created tuft, producing a low level loop.

There are three broad classes of patterned carpets produced on tufting machine:

(a) Multi pile height plain coloured carpets by tufting pre-dyed yarns. In this context, blended colour effects like berber are classified as plain colour, as is a stippled carpet created by plying together two, three or four different coloured single-ply yarns.

(b) White or undyed pile yarn may be tufted into a cut pile, a high/low loop pile, or cut/loop pile carpet.

(c) Patterns may also be created in the carpet pile by using the ‘buried end’ technique, and two or three different pre-dyed pile yarns to create patterns using this principle. The feed rate of individual ends of pile yarn on the tufting is controlled by one of the following mechanisms.

The principle of the ‘buried end’ technique is important and if a tufting machine is threaded up with alternate ends of different colours, e.g. black, white, black, white, black, white etc, three different coloured areas can effectively be created in the high pile. If the feed rate of black yarns is normal and for all white yarns it is reduced, the black yarns will form higher level loops than the white yarns, effectively ‘burying’ them and creating a black area. Conversely, if the feed rate of the black yarns is reduced, while maintaining a normal feed rate for the white yarns, a white area will be created.

If both black and white pile yarns are supplied at a normal rate, both will create high tufts and a black and white stipple. If both are supplied at the lower rate, again a black and white stipple will be created but at a lower pile height. Note that in the case where there is a single coloured area, every alternate feed yarn ‘end’ is forming a low pile tuft. This high loop of single colour reduces the pile density of the areas by 50% (the low pile may contribute a little to the density by supporting the alternate high pile ends).

This patterning technique which effectively creates three colour areas i.e. A, B and A/B stipple in both high and low pile area was a breakthrough at the time of development in the late 1960s but it is quite restrictive to the designer.
Modern machines are capable of creating loops of 6 or 8 different heights, thus enabling multiple shades in the pattern between the contrasting colours. Some carpets have been produced using an A, B, C threading of the tufting machine. This makes theoretically a greater range of colours available in this thread up, i.e., A, B, C, A/B stipple A/C stipple B/C stipple A/B/C stipple and a low or high pile ABC stipple. While this system does produce a more colourful effect, it is very difficult to control as the single colour areas (i.e. A, B, or C) have only one end in every three high, and so perform very poorly. They also do not effectively disguise or bury the adjacent two colours. The overall effect of various stippled areas creates a very ‘busy’ effect.

The A, B threading may also be used to tuft white yarns of differing dye affinities. For instance, two types of nylon which dye to different colours in the same dyeing process may be tufted in the undyed state. Pattern areas can be created the same as with normal coloured A, B, threaded yarns, and the pattern will appear when the carpet is dyed by the appropriate process.

There are three or four grades of nylon with differing affinity for acid dyes and another which can only be coloured by cationic dyes. The attraction to the carpet manufacturer of the differential dye process was that a stock of undyed (griege) carpet could be tufted and then dyed to order resulting in a reduction of ‘coloured carpet’ stock holdings.

As each of the types of undyed nylon will more than likely have a very similar appearance, loading the correct sequence of cones on the yarn creel, to produce the A, B, A, B, A, B, etc sequence at the needles requires care.

To assist, at least one of the yarns should be purchased in a tinted state from the yarn producer. The light coloured tint is designed to be removed during the dyeing processes so there is no effect on the final colour of the carpet pile.

**Eccentric Cams on Yarn Feed Rolls**

In addition to the normal feed rolls which draw the pile yarns through the tubes from the cones on the creel, the yarn can be threaded around a roller made up of sections of eccentric cams. These have the effect of regularly increasing and decreasing the rate of feed of the pile yarn in specific areas of the carpet.

The effect is to create small variations of pile height in the carpet pile. The pattern area can only be small and there is no sudden change between high pile and low pile areas. The change is gradual and occurs over two or three tufts.

**Multi-Roll Feeds**

On a 3.66 m wide tufting machine, patterns can be produced by threading the pile yarns in a pre-arranged sequence through a multiple set from four to nine full width rollers. These rollers replace the standard feed rollers of a plain tufting machine.
Each roller has a two speed drive which can be controlled independently by two magnetic clutches running at different speeds. The roller speed is controlled by the energised clutch and the amount of yarn fed is regulated, according to a pre-arranged sequence, to produce high and low tufts as desired.

The pattern produced is limited by the number of feed rollers, where each yarn can go through only one of the numbered four to nine rollers, and by the threading sequence through these rollers. There are various ways of energising each drive clutch at one of its possible speeds. The original method is the illuminated pattern drum and photocells.

A translucent pattern drum is mounted with a light source (lamp) inside it. Light sensitive photocells are employed as scanning devices. The light is directed through the shell of the drum towards the bank of light sensitive cells, and the light is intermittently interrupted by the design as the drum rotates past the fixed photocells.

The design, in the form of an opaque black ink on transparent acetate, is affixed to the face of the pattern drum. As the pattern drum rotates, the opaque and clear areas on the drum shell cause intermittent beams of light to fall on the light sensitive cells, which in turn activate micro switches to change the current to the clutches, and so change the feed roller speeds high to low or low to high.

The pattern drum rotation is coordinated with the backing cloth speed so that the length of pattern painted on the pattern on the drum surface is reflected in a corresponding length of raised tufts in the carpet.

The pattern drum system has been replaced by computerised controllers. Modern machines are usually controlled by servo motor systems that have allowed more pattern effects to be achieved.

Multi-roll feeds are suitable for producing a wide range of smaller geometric designs.

**Single-End Scroll-Type Attachment**

This system uses the principle of ‘robbing back’ yarn from the previous tuft, to produce low pile. The device consists of a series of yarn feed rolls which can be driven at two different speeds, to produce high or low pile tufts. The roll speed is controlled by a magnetic clutch which in turn is controlled by a micro switch operated via photocell by the clear or opaque areas of a pattern.

From each yarn feed roll a group of yarn tubes carries ends of pile yarns to various positions evenly spaced across the machine. Each tube carries only one end of yarn and supplies a single needle in a pattern repeat.

Usually, a repeat is approximately 18 inches (45 cm) wide. This is 116 ends on a 5/32” gauge or 96 ends on a 3/16” gauge tufting machine.
Using the 3/16” gauge tufting machine as an example, the machine would have 96 individually controlled yarn feed rolls, each of which would control 8 ends. The yarn is delivered to evenly spaced needles so that 8 repeats of the 18 inches (45 cm) wide patterns are produced across the tufting machine width, manufacturing the 12 foot (3.66 m) wide broadloom carpet.

By passing each pile yarn through two yarn feed rolls in sequence, and by controlling the two sets of feed rolls from two different pattern drums, it is possible to create a third pile height in loop pile carpet by combining A/B threading with the Single-end Scroll Attachment. This was often sheared to create a cut pile area of different colour effect.

The pattern drum unit, which includes the photocell sensors is usually positioned adjacent to the tufting machine. However, the unit is susceptible to excess heat, vibration and dust. To reduce the problem, the unit can be located remote from the tufting machine although this is inconvenient for the machine operator.

The designs are painted with opaque paint on a transparent plastic film with the disadvantage that during the process of taping the design to the pattern drum, and in removing it, the design may become scratched. These scratches can allow light to ‘bleed’ and activate the photocell sensors resulting in faulty reproduction of the pattern in the carpet.

Most carpet manufacturers use a photographic process to produce duplicates of the original design, so that damaged copies can be replaced and repaired. The distance of the bank of photocells from the surface of the pattern drum is critical, and is normally adjusted to be as close as possible to the surface of the pattern wrapped around the pattern drum, without touching it.

**Video Tuft**

The painted acetate roll has now been superseded by video tuft. The principle is the same as the photocell drum but each end is controlled by a microchip.

This gives more positive and direct control of the yarn therefore enabling the machine to produce clearer and geometric designs. An advantage is that changeover time is significantly reduced.

**Universal Pattern Attachment**

A pair of yarn feed rollers have alternate bands of smooth and textured surfaces along the length. They are driven at different speeds, one rotating twice as fast as the other. The textured areas of each roller correspond to the other. The yarn will be driven by the textured roll and the smooth roll will have no effect. These attachments are now used mainly by rug manufacturers.

A series of solenoid controlled fingers guide the yarn from the textured surface of the slow roll to the textured surface of the fast roll, and so increase the rate of yarn feed. The solenoids are operated by micro switches activated by a relief pattern on an 18 inch (45 cm) circumference pattern drum. The attachment is rarely used now.
Mohasco Slat Attachment

This mechanical pattern attachment controls the yarn feed in order to produce high and low pile effects. It consists of two sets of intermeshing slats on a continuously moving roller chain. The notches on the bottom set of the slats are constant but the upper slats have notches of varying heights. As the two sets of slats intermesh, the length of yarn available for each tuft depends on the extent to which the yarn is deflected by the depth of cut on the pattern slat.

A disadvantage of this attachment is the sets of slats may be many metres long and cutting them is very time consuming for the 250 slats that may need to be produced. The single end scroll mechanism has replaced the Mohasco attachment.

Formation of Cut and Loop Tuft via Single End Scroll

The method of forming both cut tufts and loop tufts has been mentioned previously (refer page 84). A cut loop structure can be produced on a cut pile machine via the pile yarn feed to a needle being reduced with the resulting formation of a lower loop pile tuft. The yarn feed is controlled by a single end scroll mechanism. The tufter is fitted with special hooks that have a spring clip that retains stitches to be cut, and release stitches when a reduced yarn feed is delivered to form a loop. Transition from cut to loop is not as precise as the Level Cut Loop process.

Stitch Placement Mechanism

Stitches can be displaced sideways during tufting to avoid placing tufts in straight lines. This can improve the ‘cover’ on coarser or wider gauge machines, help break up any streaks caused by yarn irregularities and improve the edge stability when the carpet is cut.

The shift can be created by:

- moving the backing, particularly on loop pile structures
- using a sliding needle bar, which moves the needles sideways.

Needle bar movements are usually controlled by mechanical cam action, and can vary from ‘wiggles or shift’ to a definite series of steps. Needle movements can be anything from simple ‘zig zag’ single steps through to multi-stitch, multi-step movements.

Sliding Needle Bar Attachments

Although it is possible to produce simple patterns using a sliding needle bar in which the needles are aligned in the bar in a straight line, a wider variety of effects can be produced when a sliding ‘staggered’ needle bar is used.

There are three mechanisms used to control the lateral movements of the needle bar:

(a) Cams which operate off the tufting machine drive

(b) Computer controlled Servo motors driving precision ball screw positioning of the needle bar.

(c) Hydraulic e.g. Hydrashift, where the movement is controlled by a Program Memory Module, which has a stitch pattern repeat of up to 512 steps that can be stored on a microchip similar to those used on computers. This is the most versatile method used.
Double Sliding Needle Bar

Two needle bars are used, both of which are capable of being shifted laterally. They are usually 1/4” (6 mm) apart and each bar is twice the gauge of the final carpet. The movement of each bar is entirely independent with a drive mechanism attached to each needle bar (one at each end of the machine).

There are three movement actuating/programming systems:

(a) Omnipoint which uses two ‘Supershift’ cams, capable of 48 steps
(b) Graphics which uses two ‘Hydrashift’ attachments
(c) Mosaic which uses two ‘Pneumover’ or pneumatic attachments.

These systems can produce identical pattern effects so complex multi-colour geometric designs can be produced. A wide range of designs can be produced by threading up the tufting machine with a predetermined sequence of coloured yarn, and ‘stepping’ the needles as required.

As it is difficult to predict what pattern a particular sequence of colours and sequence of needle movements will create in the carpet pile, carpet manufacturers use a computer program with all the threading and tufting data to simulate the patterns. This reduces the time spent developing new designs on the tufting machine itself.

Combinations

Some developments are a combination of new principles, variations on old ones and the advantage of computer control.

Hydrashift

This system allows precise needle placement, double jump and multiples of the gauge. A touch screen program is developed which then controls the needle bar through a data key.

Scroll Mechanism Computer Controlled

This device is an improvement on the painted pattern acetate drum. It is computer controlled and as such gives total control, with no acetate degradation. All patterns are disk stored. Variations are the extent of the control rather than the width of the acetate. It allows a full width pattern.

Hi-Fi (High Definition Cross Over Tufting Machine)

This uses the double sliding needle bar and cross over pattern. The needle bars are able to move in single gauge sets or any multiple of double, triple or quadruple.

Card Munroe Precision Cut/Uncut

Similar to Velv-A-Loop but uses cut and loop pile bars with shifting mechanisms which are a combination of mechanical cams under computer control.
Colortec
The Colortec is a cut pile system that gives individual needle control. The needles are threaded in a repeating sequence of all the colours used in the design. The needle carriers are shifted sideways to allow for the required colour in the pattern to be available. The needle is only activated when the tuft is required. Therefore, there is no buried yarn in the back. The back stitch is untidy due to loose yarn tails that result from any needle that is de-activated.

Tapistron
Similar capability as the Colortec but it uses a hollow needle with the yarn fed by highly compressed air. It tufts in a cross weft fashion and produces patterns in sequences. Gauge and density may be easily changed. This machine offers a wide range of carpet constructions with design capabilities similar to the Colortec. It can make cut pile, loop pile and a mixture of both.

Servo Control
Many of these patterning systems have been further improved by the use of servo (computer) control systems.

Yarn Retractor
These are servo driven jerker bars that are used for precision pile height changes in small scale loop pile textures. Up to 4 individually controlled jerkers can be fitted to a tufter.
Carpet Manufacturing

**Level Cut Loop**

**Velv-A-Loop**

**Colorpoint**

This is a combination Full Repeat servo scroll, shifting needle bar, repeating needle threading sequence of up to 8 colours, very high density stitch rates and special software.

These machines can produce highly detailed buried end effect patterns in up to 8 colours at a tuft density suitable for contract application. The production rate is inversely proportional to the number of colours used due to the needle bar having to shift sideways for each row of the pattern to allow for any of the colours in the threading sequence to be available to tuft in that row. The back stitch contains loose buried colour yarns that will require special finishing procedures to ensure a sound backing structure.
Level Cut Loop
This development uses special loopers to create both cut pile tufts and loop pile tufts at the same height. This gives a subtle pattern effect, with a carpet of constant density in both the loop pile and cut pile areas unlike standard cut-loop carpets.

Velv-A-Loop
This tufting machine has all loop pile on one needle bar and all cut pile on the other bar. By controlling the movement of the needle bars, a variety of textured pattern effects is achieved.

Colouring Tufted Carpets
Tufted carpet may be coloured and patterned at a variety of stages of the manufacturing process. Carpets are similar to other textile products with respect to the considerable advantages gained if they are coloured or dyed and/or patterned at the latest possible stage of the production sequence.

An economical sized (blend) or batch of stock dyed fibre will create many rolls of carpet, all in the same shade. It is economically feasible to produce much smaller quantities of a colour or pattern when colouring the carpet after it has been tufted.

It is also understandable that carpets have become firmly established as a fashion product and colouring the carpet at the latest possible stage allows greater flexibility for the manufacturer as there is reduced pressure to commit to particular colours with the increased risk and cost of holding large stocks of slow moving colours.

As a consequence of later stage colouration, the manufacturer can rapidly respond to changes of design and colour in the market place and at the same time, offer a large range of colours and patterns.

While this may be seen as an ideal situation and recent advances in fibre and dyeing technology have made the dyeing of most carpet styles and fibre types possible, some styles by their very nature must be dyed at an earlier stage. For example, wool berbers, heather and tweeds are produced by blending together fibres dyed to various colours at the fibre stage.

Loading fibre to be dyed
Dyed fibre ‘cake’ on carrier
Differential Dyeing

Multi-colour effects can be obtained in the one dyeing process by using fibres of different dye affinities and selecting dyestuffs to colour them appropriately.

Yarns can be spun from fibres of a single dye affinity (or dyeing characteristics) and be tufted into a distinct pattern, alternating with other yarns of differing dye affinities. The 'buried end' technique is commonly used to create the areas of pattern in the carpet.

A yarn may also be created using proportions of two or three fibres at different dye affinities, blended together. When dyed, these yarns will create 'blended', 'heather' or 'tweed' effects, depending on the proportion of blending fibres in the yarn.

Different dye effects can be achieved with different types of polyester, acrylic and nylon. Nylon is the most commonly used fibre in these 'differential dyeing systems' and the effects of the particular dyes may be influenced by:

- varying the degree of crystallinity in the fibre through changing the extent of drawing during the extrusion/spinning process
- varying filament linear density and cross-sectional shape
- varying the amount of delustrant added to the molten polymer prior to extrusion
- effective heating process during fibre production, texturing and setting
- chemical modifications of the polymer.

Fibre or Loose Stock Dyeing

If loose stock dyeing is to be the colouration stage, the fibres are dyed in batches that are combined and blended together to create the final coloured blend to be spun into yarns. Colour adjustments may be made by adding small amounts of fibres dyed to the appropriate shade and blended into the bulk lot to achieve the desired shade. Dyeing is carried out in a stainless steel vat and hot dye solution is pumped through the fibre mass. Stock dyeing produces a high standard of shade levelness in the final carpet and maximum fastness of dye colours.

Hank Dyeing

In this process, the colour is applied to yarn that has been wound into hanks. The hanks are suspended on sticks. The dye liquor is circulated through the hanks. In the more modern machines, a lower stick is also used to prevent movement of the hanks and associated yarn tangling and felting.

Lease tie bands are yarns that are tied around the yarn bundle at various points in the hank to reduce yarn tangling.
For nylon and wool hanks, the lease yarns are often polyester which are removed prior to hank-to-cone winding – the next process after dyeing and drying.

There is little colour variation between hanks dyed in the same vat but due to slight shade variations batch-to-batch, yarns from different batches should not be mixed in a plain carpet. They can, however, be mixed for use in patterned carpets that utilise a number of different coloured yarns in the design.

The dyeing process depending on its cycle time and temperature conditions will 'twist set' the yarn to varying degrees particularly those yarns with wool fibre content. In the case of knit-de-knit yarns, a steaming process carried out in an autoclave will be necessary to set the kink in the yarn.

**Space Dye Effects**

By partially immersing the hank in the dye bath, one segment of the hank is dyed to colour number 1. The bottom pegs are rotated in unison and another segment of the hank is dyed to colour number 2 which has replaced the first colour in the dyebath. This method gives relatively long sections of each colour e.g. 40 mm lengths of yarn which creates a very different and distinct colour effect in the carpet pile.

Finer definition space dyed effects can be obtained by printing the yarn with fine line colour stripes using a series of small rubber covered rollers. Combining this method of colouration with a knit-de-knit process where the yarn is in the form of a continuous circular knitted 'sock', can create a very subtle printed effect.

After the yarn has been printed or dyed by any of the above methods, it must be washed to remove excess dyestuff and then dried.

**Package Dyeing**

Recent improvements in the design of package dyeing machines and the construction of larger pressure dyeing vessels has made package dyeing a viable alternative to hank dyeing. An advantage is that the packages used for dyeing can go straight onto the tufting machine creel.

To obtain an even or level dyeing between packages or cones and throughout each individual package, the seal between each cone, liquor flows and winding tension within each package must be consistent and controlled.

**Carpet Batch Dyeing**

The advantages of dyeing the carpet in the tufted form have led to many innovations in this area. An additional driving force for improvements in carpet dyeing has been the need to improve the efficiency of the dyeing process. Increasing energy costs and dyestuff costs and stricter environmental controls on dyehouse effluent, have created pressures for improved carpet dyeing methods.

Two major problems that prevented an earlier adoption of dyeing in the carpet form were:
- distortion and damage of the carpet pile by mechanical action in hot dye liquors (solutions of dyestuff and other chemicals in water)
- distortion and shrinkage of the carpet width and length frequently causing cockling.

Other problems relating to the continuous dyeing and printing methods involved the effective control of dye uptake rate (strike rate), washing off of excess dyestuff, and ‘fixing’ of the dyestuff to the fibres.

**Winch or Beck Dyeing**

The method of dyeing tufted carpet in the winch or beck involves the carpet being driven slowly through the hot dye liquor by a large winch wheel. Pumps circulate the dye liquor and evenly distribute the heat to improve the levelness of dyeing.
The carpet is sewn end-to-end to form a continuous loop and may be dyed in ‘rope’ or ‘open’ form. If carpet is dyed in the rope form, it is easier to get an even depth of colour across the width. However, the pile may become permanently distorted due to crushing and creasing.

In open width dyeing, scroll rollers or expander bars and centering devices are used to maintain the carpet at an open width. Open width dyeing reduces pile distortion but it may be more prone to colour variation within the carpet.

Most winches and beck units are enclosed. There are also models which can be pressurised to increase the rate of dye exhaustion and so decrease the dyeing time.

While Nylon pile carpet has been frequently dyed by this method and 150 metres of carpet can be dyed in one batch, this method has been largely replaced by continuous dyeing which has a production output equivalent to 10 -15 beck units.

One advantage of the beck unit over continuous dyeing methods is that there is less tendency for end to end shade variation.

A potential problem with all methods of dyeing carpet as an unbacked tufted structure, where the pile yarns are not locked firmly within the carpet substrate, is the snagging of a pile loop or back stitch on a protruding machine part.

**Continuous Carpet Dyeing**

Dye auxiliary chemicals and equipment have been developed to the stage that carpets of many styles and fibre contents can be successfully dyed in this process.

The development of continuous dyeing and new printing methods has occurred hand-in-hand and many carpet colouration production lines include equipment for both dyeing and printing. The two processes are often used on the same carpet.

The basic stages in these processes are:

- pre-wetting to allow better dye penetration
- dye application
- steam fixation
- wash off loose dyestuff
- drying which may also incorporate a vacuum extraction stage.

**Carpet Printing**

The principles of carpet printing are similar to these of continuous carpet dyeing. The steps consist of colour application by a variety of methods, dye fixation by steaming, wash off of excess dyestuff and drying.

The dyestuff can be applied via three devices:

- dye liquor, applied by individually controlled spray jets
- dye paste applied by printing blocks or by squeegees through a screen
- foam applied by individually controlled nozzles.
The control of the carpet speed and carpet position and a constant relationship to the repetition speed of the printing device so the created pattern has a regular repeat is critical during the printing processes. The printing devices are usually placed in series so a number of colours can be applied to create the desired pattern. The devices must be strictly synchronised and be an exact distance apart for the pattern to be precise.

Overprinting devices usually follow a continuous dyeing unit which creates the base or background colour.

**Stalwart Printing**
While this was the first method used to print carpets, it is still in use. The units can apply up to four colours and usually operate in line with a pad/mangle continuous dye unit that applies a ground colour. Additional colour effects are created by overprinting.

The print rollers are usually constructed of wood and have foam rubber shapes attached to the surface. Each roller rotates in a trough filled with dye liquor to impregnate the foam rubber shapes. The roller then presses against the pile of the carpet and the dye liquor is squeezed into the carpet pile.

In addition to foam rubber, a variety of materials can be used to create the pattern shapes and to alter the amount of dye transferred to the carpet pile.

Other materials including foam rubber sandwiched to a harder rubber base, flocked material on a rubber base, and dimple-type textured rubber will all give different print effects.

Although the Stalwart unit is relatively cheap and simple to operate, it has some restrictions in relation to the penetration of dye into the pile and can only produce pattern shapes that do not require a high level of definition.

**Screen Printing**
Flat bed screen printing was adopted from the frequently used fabric printing method.

There are two systems:

- where the carpet is laid out on a table and a series of screens moved down the table, each stopping to apply its colour in turn
- where the carpet moves forward one repeat at a time (up to 2 m x 4 m area), under a set of screen stations which move down and print their colour.

One or two roller squeegees (or flat rubber squeegees) force the dye paste through the tightly stretched woven polyester screen. Areas which are not required to be printed are blocked out with an opaque paint.

Although fine line designs can be reproduced in up to ten colours, the amount of penetration of dye into the pile is a problem. As a result, most screen printed carpets whether printed by flat bed or roller screen processes are restricted to low profile nylon pile styles. The BDA machine incorporates a vacuum slot to aid the penetration of the dye paste.

The Zimmer flat bed screen printing system uses electromagnets to control the squeeze pressure and therefore the dye paste penetration. Up to six screens work together.
Rotary screen printing is a continuous method of printing multi colour patterns where the carpet moves at a constant speed under a series of rollers, each of which applies a separate colour to the carpet pile.

The rotary screens are 4 metre long cylinders with a circumference of between 1.0 metre to 2.4 metres. They are made of thin metal which is often nickel. The design is formed by small perforations in the roller surface and the dye paste is forced through these perforations. This is similar to dye paste being forced through the weave of the strong woven fabric of a flat bed screen.

The pattern repeat will be the circumference of the roller, i.e. 1.0 metre to 2.4 metres, and as with all screen printing processes, total dye penetration from the tip to the base of the tuft is not possible.

The Zimmer rotary machine uses a squeegee system and two rods squeegee the dye paste under pressure.

The Mitter rotary printer incorporates a large revolving roll squeegee that is fed from a constant well. An inflatable air sleeve ensures constant pressure on the roller and an even dye penetration into the carpet pile.

All rotary systems have two advantages over flat bed systems: they are continuous and require less space.

**Splatter Printing**

TAK dyeing is a splatter method of applying colours in a relatively random fashion onto a pre-dyed carpet pile.

The essential elements of the system are a doctor blade which transfers the dye paste from the dye applicator roll to a lateral moving serrated belt. Serrations on the doctor blade channel the thin paste (liquor) into streams which are broken up into drops by:

- the reciprocating movement of the serrated doctor blade
- the moving serrated belt
- the drop cutters which are rows of hooked pins.

A number of units can be used in series and different random patterns can be obtained by varying the speeds of the moving components of the system. Light coloured effects can be created on a darker ground shade through the use of resist chemicals in the dye liquor in the appropriate dye troughs. Spray systems of continuous dyeing and printing have been modified to enable the creation of intricate multi-coloured systems.

The Millitron system was one of the first computer controlled micro jet colour injection dyeing systems. A second set of computer controlled air jets control the jets of dye spray after they have been ejected by the first set. The unit has high production speeds with good colour penetration of the whole of the tuft above the primary backing fabric.

Using colour computer controls, patterns can be changed instantaneously with no waste carpet if the same colourway is used.

**Foam Printing**

Foam printing is a development of the Kuster continuous foam dyeing process. Dye liquor is converted to foam and applied to the carpet by a series of nozzles. The nozzles sit on a pair of bars that can be reciprocated independently.

The foam then moves from the reciprocating nozzles to a revolving application roller where wire fingers randomly apply the foam onto the roller. The foam is then transferred by a doctor blade to the carpet pile.

A series of colours are used in the different nozzles and a computer program opens and closes the foam nozzles. The speeds of all moving components are variable. The system produces subtle, random designs of a longer repeat than the TAK system.
Transfer Printing
Transfer or sublimation printing is commonly used for delicate fabric designs and has been developed for use on low profile carpets.
The design is pre-printed in reverse on a roll of paper which is pressed against the carpet pile at high temperatures. The system produces relatively poor penetration of colour into the carpet pile.

Carpet Tiles

General
In recent years, the sector of Carpet Tiles has established a strong position within the carpet industry. It is focused mainly on contract applications. Their increased popularity is due to a number of advantages:

- styling possibilities such as mixing of plain and patterned tiles within an installation - laying in different directions e.g. at 90 or 180 degrees, having borders, printing on sophisticated equipment to produce specific or individual requirements and designs. In some cases, tiles can be printed individually giving the possibility of intricate designs capable of being pieced together to form large areas of patterns
- the ability to lay both broadloom and tiles in the same installation using the same base carpet
- easier transport to locations in multi storey buildings
- damaged tiles can be replaced (depending on the age of the installation)
- easy access to flat cable laid on sub-floors and to services in raised sub-floors
- easier refurbishment in occupied buildings/offices - less interruption and more convenient
- tiles are now much more affordable due to lower pile weights and pile thickness profiles resulting in similar or better performance characteristics
- tiles combined with cost effective installation offers overall cost benefits when compared to broadloom installations.

Tile Substrates
Tiles may be based on needled, tufted, bonded, flocked or woven carpets and are made for all market levels.
In general, the majority of carpet tiles are installed using pressure sensitive glues, making replacement a much quicker and easier task.
Tile Backings
A tile backing needs to be engineered to enable a carpet to meet the general requirements for tiles:

- an appropriate thickness to cover minor imperfections in the floor
- good dimensional stability – resistance to shrinkage, arching and curling
- high mass per unit area particularly in the case of self-laying tiles
- ‘controlled’ flexibility to assist in installation (uncontrolled flexibility is likely to result in tiles moving)
- accurate dimensions with non-fraying clean cut edges.

Backings materials are used to provide mass, thickness and a required degree of flexibility. Dimensional stability is generally achieved by the inclusion of at least one glass fibre scrim but it is not absolutely necessary in all backing types.

Polyvinylchloride (PVC) and bitumen are the most commonly used backing polymers sometimes in conjunction with non woven cushion pad for underfoot comfort. Other backing polymers in use are Atatic polypropylene (APP), Vinyl acetate/ethylene (EVA), Polyurethane and Low density polyethylene (LDPE).

There is little or no difference in the installation and performance of tiles with different backings as generally all require laying by experienced installers working to a carefully prepared installation plan to achieve the best result.

Tile Cutting and Finishing
Die stamping has been and continues to be the most effective way to cut tiles into very accurate dimensions, usually either 500mm x 500mm or 18 inches x 18 inches, although there are still many tiles cut to other sizes such as 600mm x 600m and even 1m x 1m.

Specific sizes are sometimes called for to meet certain requirements like raised floors for communication and electrical cables.

Cut pile tiles and some cut-uncut constructions require shearing and this is generally done in carpet form prior to conversion into tiles. Some tiles that may have been printed as the final stage could require shearing while in tile form and this is carried by a specific narrow width shearing machine.

After producing the tiles, during which directional arrows are printed on the back to ensure correct installation, they are generally stacked into boxes, face-to-face/pile-to-pile and back-to-back, usually about 16 tiles or 4 square metres to a box but this can vary depending upon the total tile thickness, tile weight and in some cases, customer requirements.
Tile Patterning

The patterning scope of tiles can be achieved by die cutting, yarn effects, use of tufted and woven patterned substrate or in bonded tiles by using the patterning systems of the Bondax or Axtile processes.

Printing is another colouration and patterning option. Computer controlled jet printing is a most flexible system for introducing pattern to tiles. The register between tiles is very accurate and if required, designs can have repeats covering several tiles or be non-repeating. Machines in versions specific to tile printing are widely used in the tile manufacturing sector. The combination of jet-printed tiles and plain colouration tiles opens up a further avenue to enhance the on-floor patterned effect.

Screen printing is the principal system used for flocked tiles. The Westprint system developed to print Westbond tiles, consists of printing and steaming with no print afterwash being required.

A dry system involving heat transfer from impregnated paper can be used in short runs to overprint detailed emblems and photographic images on low pile thickness flocked, needled or tufted nylon tiles that have a pale background pile colour.

Following printing, the tiles with their directional arrows on the back to ensure correct installation, are stacked in boxes, face-to-face/pile-to-pile and back-to-back usually about 16 tiles or 4 square metres to a box but this can vary depending upon the total tile thickness, tile weight and in some cases, customer requirements.
### Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibacterial</td>
<td>A treatment that destroys bacteria or suppresses their growth or their ability to reproduce</td>
</tr>
<tr>
<td>Antimicrobial</td>
<td>A treatment that can be added to the carpet to reduce the growth of common micro-organisms such as bacteria, fungi, yeast, mildew and mould</td>
</tr>
<tr>
<td>Antistatic</td>
<td>The ability of a carpet to dissipate an electrostatic charge</td>
</tr>
<tr>
<td>Backing</td>
<td>A woven or non-woven fabric that has yarn inserted into it (tufting) or onto it (bonding). Secondary backing – a fabric latexed to the back of the carpet to reinforce and increase dimensional stability</td>
</tr>
<tr>
<td>Berber</td>
<td>Loop pile carpet tufted using thick yarn that has random specks of colour in contrast to the base colour. This textile floor covering has a comfortable feel and maintains an informal casual look</td>
</tr>
<tr>
<td>Bond Strength, Backing Adhesion</td>
<td>The adhesion of a secondary backing to the primary backing</td>
</tr>
<tr>
<td>Broadloom</td>
<td>A term used to denote a carpet width of 1.83m or more</td>
</tr>
<tr>
<td>Bulked Continuous Filament (BCF)</td>
<td>Continuous strands of synthetic fibre formed into yarn bundles of a given number of filaments and texturised to increase bulk and coverage</td>
</tr>
<tr>
<td>Buried End</td>
<td>A mechanism on a tufting machine that allows yarn in the surface pile to be hidden or visible according to a designated pattern/ design</td>
</tr>
<tr>
<td>Chain Yarn</td>
<td>Chain warp threads usually woven in pairs, alternating over and under the lower shot and one or more top shots, which are then bound enclosing the stuffer yarns and the tufts or loops forming the pile</td>
</tr>
<tr>
<td>Cockling</td>
<td>A wrinkled appearance on the carpet surface in which yarn non-uniform relaxation or shrinkage may have occurred</td>
</tr>
<tr>
<td>Combed</td>
<td>Carded, gilled and roved wool fibres. Combing aligns and straightens the fibre as well as reducing the percentage of short fibre content</td>
</tr>
<tr>
<td>Construction</td>
<td>The manufacturing method and the final arrangement of fibre or yarn and backing materials in the carpet as stated in a given specification</td>
</tr>
</tbody>
</table>
# Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coverage</strong></td>
<td>The carpet surface is composed of an appropriate tuft density that does not expose any of the primary backing</td>
</tr>
<tr>
<td><strong>Cut Pile</strong></td>
<td>Carpet surface composed of legs of tufts or cut ends of pile fibre or yarn</td>
</tr>
<tr>
<td><strong>Cut and Loop</strong></td>
<td>Carpet surface composed of a combination of cut and uncut ends (W-shaped tufts) of different lengths or of the same length of pile yarn</td>
</tr>
<tr>
<td><strong>Decitex or dtex (of either fibre of filament yarn)</strong></td>
<td>A system of designating fibre or yarn ‘count’ – a measure of weight per 10,000 metres</td>
</tr>
<tr>
<td><strong>Delamination</strong></td>
<td>Separation of backings through loss of adhesion between the secondary backing and the primary backing</td>
</tr>
<tr>
<td><strong>Denier (of either fibre of filament yarn)</strong></td>
<td>A system of designating fibre or yarn ‘count’ – a measure of weight in grams per 9,000 metres</td>
</tr>
<tr>
<td><strong>Density - Tuft</strong></td>
<td>The number of tufts within a defined unit length</td>
</tr>
<tr>
<td><strong>Dimensional Stability</strong></td>
<td>The ability of the carpet to retain its original size and shape. Secondary backing adds dimensional stability to the carpet</td>
</tr>
<tr>
<td><strong>Direct Stick</strong></td>
<td>An installation method where the carpet is adhered directly to the floor</td>
</tr>
<tr>
<td><strong>Face-to-Face Woven Pile Carpet</strong></td>
<td>Carpet manufactured on a weaving machine that produces simultaneously, face-to-face, two ground weaves joined by pile yarn, which are divided by the cutting motion of the knife producing a ‘Bottom’ carpet and a ‘Top’ carpet</td>
</tr>
<tr>
<td><strong>Face-to-Face Bonded-Pile Carpet</strong></td>
<td>Pile carpet manufactured on a machine that produces face-to-face textile floor coverings, with the pile forming material passing alternatively from one substrate to another, where it is fixed by adhesive. Two cut pile carpets are made by cutting the pile-forming material between the two substrates</td>
</tr>
<tr>
<td><strong>Filament</strong></td>
<td>A single continuous strand of natural or synthetic fibre</td>
</tr>
<tr>
<td><strong>Frieze or Hard Twist</strong></td>
<td>A cut pile textured (kinked or curled effect) carpet where the texture is due to the tightly or highly twisted pile yarn. These yarns are generally referred to as ‘hard twist or high twist yarns’</td>
</tr>
<tr>
<td><strong>Fuzzing</strong></td>
<td>Hairy effect on the carpet surface that may be caused by fibres slipping partially out of the yarn due to wear or vacuum cleaning and, not removed by brushing or suction</td>
</tr>
<tr>
<td><strong>Gauge - Tufting</strong></td>
<td>The distance between two needle points. Expressed in fractions of an inch, 1/8 gauge – 8 needles per inch and converted to metric - 31.5 per 10cm</td>
</tr>
<tr>
<td><strong>Hand - Handle</strong></td>
<td>The tactile aesthetic qualities if carpet and textiles – how it feels to the hand</td>
</tr>
</tbody>
</table>
# Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanking – Reeling - Coiling</td>
<td>Yarn is wound into hank form via a ‘hanking’ or ‘reeling’ machine for the scouring, setting or dyeing – all batch processes. For continuous setting, a coil of yarn is formed via a ‘yarn coiler’</td>
</tr>
<tr>
<td>Hard Twist</td>
<td>See Frieze</td>
</tr>
<tr>
<td>Heat Setting</td>
<td>A process that ‘sets’ the twist in the yarn by heat or steam, enabling the yarn to hold its twist during the performance life of the carpet. For cut pile carpets, natural fibre, synthetic fibre/ filament or blends of natural/ synthetic yarns are generally always ‘twist set’</td>
</tr>
<tr>
<td>Knit-de-Knit</td>
<td>Yarn is knitted into a sock form and space dyed. The yarn is then de-knitted (rewound from the sock). This process is used to create an irregular colouration effect on the yarn</td>
</tr>
<tr>
<td>Level Loop Pile</td>
<td>Pile of a carpet consisting of uncut loops of the same height or thickness</td>
</tr>
<tr>
<td>Loop Pile</td>
<td>Carpet surface composed of uncut loops</td>
</tr>
<tr>
<td>Lustre</td>
<td>Brightness or sheen of fibres, yarns or carpet</td>
</tr>
<tr>
<td>Measured Surface Pile Mass Density</td>
<td>Ratio of mass to volume of the pile above substrate measured under standard pressure, calculated from the pile thickness and the mass of pile above substrate</td>
</tr>
<tr>
<td>Micron</td>
<td>Measure of diameter or thickness applied to the wool fibre. The unit of measure is 1 millionth of a metre</td>
</tr>
<tr>
<td>Outdoor Carpet</td>
<td>A carpet that is used outdoors e.g. synthetic surfaces for sporting activities</td>
</tr>
<tr>
<td>Pile</td>
<td>The part of a textile floor covering consisting of textile yarns or fibres, cut or looped or in combination, projecting from the substrate and acting as a use-surface</td>
</tr>
<tr>
<td>Pile Height</td>
<td>Also called the nap, pile height is the length of the tuft measured from the primary backing to the yarn or tuft tip.</td>
</tr>
<tr>
<td>Pile Thickness</td>
<td>Difference in the thickness of the carpet before and after the pile above the substrate has been shorn away, measured under standard pressure of 2kPa. This measurement takes into account pile lay, measured at 2kPa - just sufficient to buckle protruding fibres without compressing the pile. See page 353 Carpet Manufacture</td>
</tr>
<tr>
<td>Pile Crushing</td>
<td>Loss of pile thickness by compression and blending of tufts caused by traffic wear. Tufts may collapse into the space between each tuft. The effect may be irreversible if the yarn has inadequate resilience or the textile floor covering has insufficient density (calculated from the surface pile mass &amp; pile thickness relationship) to meet the traffic conditions in the installation</td>
</tr>
<tr>
<td>Pile Reversal</td>
<td>One condition of Pile Reversal is noted when brushing velvet pile against the pile direction. This effect can be reversed as it is a temporary condition. Permanent Pile Reversal is an irreversible localized change in orientation of the pile of a textile floor covering, the boundaries of which often assume a rough, matted texture due to the confluence of pile lying in normal and reverse directions. Also referred to as Water Marking, Puddling, Pooling, Permanent Pile Shading. See CIAL Shading Brochure</td>
</tr>
</tbody>
</table>
Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilling - Cobwebbing</td>
<td>The first stage of Pilling is Fuzzing (where a hairy effect is noted on the carpet surface that may be caused by fibres slipping partially out of the yarn due to wear or vacuum cleaning and, not removed by brushing or suction). Pilling is noted when fibres from the same tuft or from different tufts become entangled with one another, forming fibre balls, an interlaced web of fibres and/or entangled tufts.</td>
</tr>
<tr>
<td>Pitch – Axminster</td>
<td>Number of binding sites in 25.4mm (1 inch) of width</td>
</tr>
<tr>
<td>Pitch - Wilton</td>
<td>Number of binding sites in 686mm (27 inch) of width</td>
</tr>
<tr>
<td>Pitch – hand made carpets</td>
<td>Number of knots per square inch in the pile</td>
</tr>
<tr>
<td>Plush</td>
<td>Often referred to as velvet carpet, plush carpet or velvet plush carpet – a cut pile carpet with pile yarns with very little twist so that the ends tend to blend together to give a smooth, unbroken surface with no tuft definition</td>
</tr>
<tr>
<td>Ply - Fold</td>
<td>2ply or 2fold – the number indicating how many single ends have been twisted together to form the finished yarn</td>
</tr>
<tr>
<td>Power Stretcher</td>
<td>A carpet installation tool used to stretch carpet to prevent ripples, wrinkles or ridges (buckling or rucking) once the carpet is in-service</td>
</tr>
<tr>
<td>Resilience</td>
<td>Ability of carpet pile or underlay to recover its original appearance and thickness after being subjected to compression from static loads (furniture) and dynamic loads (walking traffic)</td>
</tr>
<tr>
<td>Saxony</td>
<td>A cut pile carpet, utilizing straight, twist set pile yarns, resulting in a smooth surface with tuft definition</td>
</tr>
<tr>
<td>Seam</td>
<td>In a carpet installation, the line formed by joining the edge of two pieces of carpet by using the appropriate seaming tape, hand sewing or other techniques</td>
</tr>
<tr>
<td>Seam Joining</td>
<td>Procedure of coating the trimmed edges of two carpet pieces, to be joined, with a continuous bead of adhesive to prevent fraying (damage or loss of pile or substrate material of a textile floor covering from a cut edge) or unravelling at the seam</td>
</tr>
<tr>
<td>Setting – Yarn</td>
<td>Setting of the twist in yarn via boiling water, steam or chemical</td>
</tr>
<tr>
<td>Setting - Spools</td>
<td>For Spool Gripper Axminster , spool setting is the operation where the pile yarn for each weftways row is wound on a separate spool</td>
</tr>
</tbody>
</table>
### Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shading</strong></td>
<td>A change in the appearance in the surface pile of a textile floor covering due to a difference in light reflection because of localized alterations in the orientation of the fibres or tufts. Also see ‘Pile Reversal’</td>
</tr>
<tr>
<td><strong>Shot</strong></td>
<td>Weft yarn within the woven carpet resulting from one operation of the weft insertion mechanism</td>
</tr>
<tr>
<td><strong>Sisal</strong></td>
<td>A vegetable fibre replicated in other natural and synthetic fibres offer a variety of textures, patterns and prints</td>
</tr>
<tr>
<td><strong>Soil Retardent – Soil Resist</strong></td>
<td>A chemical finish applied to fibres/ filaments or the pile surface that inhibits attachment of airborne or tracked-in soil material</td>
</tr>
<tr>
<td><strong>Sprouting</strong></td>
<td>Release and appearance during use of extra-long tuft legs which were accidently trapped within the pile of a textile floor covering during manufacture</td>
</tr>
<tr>
<td><strong>Staple</strong></td>
<td>Variety of lengths of fibre converted in spun yarns (often referred to as ‘staple yarns’) or converted directly into non-woven textile floor coverings</td>
</tr>
<tr>
<td><strong>Stitch</strong></td>
<td>A single complete movement of a needle or pile insertion apparatus to form cut or loop pile</td>
</tr>
<tr>
<td><strong>Stitch Rate</strong></td>
<td>Number of stitches per unit length in the direction of manufacture</td>
</tr>
<tr>
<td><strong>Stuffer Yarns</strong></td>
<td>Warp threads that reinforce the substrate of a woven carpet</td>
</tr>
<tr>
<td><strong>Substrate</strong></td>
<td>Construction, integral with the use-surface and composed of one or more layers which serve as a support for the use-surface. The substrate can stabilize the dimensions and/or act as a cushion. Certain textile floor coverings without pile need not have a substrate distinct from the use-surface</td>
</tr>
<tr>
<td><strong>Surface Pile Mass</strong></td>
<td>Weight or Mass measured in grams per square metre of the pile or use-surface of a textile floor covering directly exposed to traffic and the conditions of the installation environment</td>
</tr>
<tr>
<td><strong>Tex</strong></td>
<td>A system of designating yarn ‘count’ – the weight of yarn in grams per 1000 metres: [R = \text{Resultant Yarn Count}] [R600/1 = 600 \text{ grams per 1000 metres}] [R600/2 = 600 \text{ grams per 1000 metres (composed of 2 ends) or this example could be written as 300/2 meaning two ends of 300 Tex have been twisted together}]</td>
</tr>
<tr>
<td><strong>Textile Floor Covering - Carpet</strong></td>
<td>A system having a use-surface composed of textile material and generally used for covering floors</td>
</tr>
<tr>
<td><strong>Textile Floor Covering With/ Without Pile</strong></td>
<td>With Pile: a textile floor covering having a textile use-surface formed from a layer of yarns or fibres projecting from a substrate  [\text{Without Pile: floor covering composed of a non-pile textile use-surface with or without a substrate}]</td>
</tr>
</tbody>
</table>
# Glossary of Carpet Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Pile (Yarn) Weight – Total Pile (Yarn) Mass</td>
<td>Mass of the pile yarn in a unit area, including that forming the base of the tufts or held in the substrate but excluding any backing compound adhering to the pile yarn, determined by weighing after separating the pile yarn from the other components</td>
</tr>
<tr>
<td>Tuft</td>
<td>Length of yarn, for example J-, U- or W-shaped or a length of yarn in the form of a knot, the leg or legs of which form the pile of a carpet</td>
</tr>
<tr>
<td>Tuft Bind – Tuft Withdrawal – Tuft Lock</td>
<td>Force required to pull the tuft leg from the carpet</td>
</tr>
<tr>
<td>Underlay – Carpet Cushion</td>
<td>Resilient layer of textile and/or other material placed between the textile floor covering and the floor</td>
</tr>
<tr>
<td>Use – Surface</td>
<td>Part of a textile floor covering directly exposed to traffic and the conditions of the installation environment</td>
</tr>
<tr>
<td>Velvet Pile</td>
<td>See ‘Plush’</td>
</tr>
<tr>
<td>Warp Yarn</td>
<td>Yarns running lengthwise in a woven textile floor covering</td>
</tr>
<tr>
<td>Weft Yarn</td>
<td>A weft yarn or filling yarn running from selvedge to selvedge at right angles to the warp in a woven textile floor covering</td>
</tr>
<tr>
<td>Woven Pile Carpet</td>
<td>Pile carpet produced on a weaving machine so that the pile is bound by interlacing with backing yarns</td>
</tr>
<tr>
<td>Yarn Ply</td>
<td>Indicates how many single ends have been twisted together to form the finished yarn</td>
</tr>
<tr>
<td>Zippering</td>
<td>The effect of yarn fraying, unravelling or pulling out at the seam join. The term ‘zippering’ is also applicable to loop pile yarns able to be pulled out of the structure when backing compound adhesion properties are reduced when an unforeseen force is exerted on one of more loops</td>
</tr>
</tbody>
</table>
### Conversion Tables

<table>
<thead>
<tr>
<th>Ounces Per Square Yard</th>
<th>Grams Per Square Metre</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>680</td>
</tr>
<tr>
<td>21</td>
<td>710</td>
</tr>
<tr>
<td>22</td>
<td>745</td>
</tr>
<tr>
<td>23</td>
<td>780</td>
</tr>
<tr>
<td>24</td>
<td>815</td>
</tr>
<tr>
<td>25</td>
<td>850</td>
</tr>
<tr>
<td>26</td>
<td>880</td>
</tr>
<tr>
<td>27</td>
<td>915</td>
</tr>
<tr>
<td>28</td>
<td>950</td>
</tr>
<tr>
<td>29</td>
<td>985</td>
</tr>
<tr>
<td>30</td>
<td>1015</td>
</tr>
<tr>
<td>31</td>
<td>1050</td>
</tr>
<tr>
<td>32</td>
<td>1085</td>
</tr>
<tr>
<td>33</td>
<td>1120</td>
</tr>
<tr>
<td>34</td>
<td>1155</td>
</tr>
<tr>
<td>35</td>
<td>1185</td>
</tr>
<tr>
<td>36</td>
<td>1220</td>
</tr>
<tr>
<td>37</td>
<td>1255</td>
</tr>
<tr>
<td>38</td>
<td>1290</td>
</tr>
<tr>
<td>39</td>
<td>1320</td>
</tr>
<tr>
<td>40</td>
<td>1355</td>
</tr>
<tr>
<td>41</td>
<td>1390</td>
</tr>
<tr>
<td>42</td>
<td>1425</td>
</tr>
<tr>
<td>43</td>
<td>1460</td>
</tr>
<tr>
<td>44</td>
<td>1490</td>
</tr>
<tr>
<td>45</td>
<td>1525</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ounces Per Square Yard</th>
<th>Grams Per Square Metre</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>1560</td>
</tr>
<tr>
<td>47</td>
<td>1595</td>
</tr>
<tr>
<td>48</td>
<td>1630</td>
</tr>
<tr>
<td>49</td>
<td>1660</td>
</tr>
<tr>
<td>50</td>
<td>1695</td>
</tr>
<tr>
<td>51</td>
<td>1730</td>
</tr>
<tr>
<td>52</td>
<td>1765</td>
</tr>
<tr>
<td>53</td>
<td>1800</td>
</tr>
<tr>
<td>54</td>
<td>1830</td>
</tr>
<tr>
<td>55</td>
<td>1865</td>
</tr>
<tr>
<td>56</td>
<td>1900</td>
</tr>
<tr>
<td>57</td>
<td>1935</td>
</tr>
<tr>
<td>58</td>
<td>1965</td>
</tr>
<tr>
<td>59</td>
<td>2000</td>
</tr>
<tr>
<td>60</td>
<td>2035</td>
</tr>
<tr>
<td>61</td>
<td>2070</td>
</tr>
<tr>
<td>62</td>
<td>2100</td>
</tr>
<tr>
<td>63</td>
<td>2135</td>
</tr>
<tr>
<td>64</td>
<td>2165</td>
</tr>
<tr>
<td>65</td>
<td>2205</td>
</tr>
<tr>
<td>66</td>
<td>2240</td>
</tr>
<tr>
<td>67</td>
<td>2270</td>
</tr>
<tr>
<td>68</td>
<td>2305</td>
</tr>
<tr>
<td>69</td>
<td>2340</td>
</tr>
<tr>
<td>70</td>
<td>2375</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ounces Per Square Yard</th>
<th>Grams Per Square Metre</th>
</tr>
</thead>
<tbody>
<tr>
<td>71</td>
<td>2410</td>
</tr>
<tr>
<td>72</td>
<td>2440</td>
</tr>
<tr>
<td>73</td>
<td>2475</td>
</tr>
<tr>
<td>74</td>
<td>2510</td>
</tr>
<tr>
<td>75</td>
<td>2545</td>
</tr>
<tr>
<td>76</td>
<td>2585</td>
</tr>
<tr>
<td>77</td>
<td>2610</td>
</tr>
<tr>
<td>78</td>
<td>2645</td>
</tr>
<tr>
<td>79</td>
<td>2680</td>
</tr>
<tr>
<td>80</td>
<td>2715</td>
</tr>
<tr>
<td>81</td>
<td>2745</td>
</tr>
<tr>
<td>82</td>
<td>2780</td>
</tr>
<tr>
<td>83</td>
<td>2815</td>
</tr>
<tr>
<td>84</td>
<td>2850</td>
</tr>
<tr>
<td>85</td>
<td>2880</td>
</tr>
<tr>
<td>86</td>
<td>2915</td>
</tr>
<tr>
<td>87</td>
<td>2950</td>
</tr>
<tr>
<td>88</td>
<td>2985</td>
</tr>
<tr>
<td>89</td>
<td>3020</td>
</tr>
<tr>
<td>90</td>
<td>3060</td>
</tr>
<tr>
<td>95</td>
<td>3120</td>
</tr>
<tr>
<td>100</td>
<td>3170</td>
</tr>
<tr>
<td>105</td>
<td>3230</td>
</tr>
<tr>
<td>110</td>
<td>3290</td>
</tr>
<tr>
<td>115</td>
<td>3350</td>
</tr>
<tr>
<td>120</td>
<td>3410</td>
</tr>
</tbody>
</table>